DISCOVERED QUESTIONS

YASH PAL AND RAHUL PAL

The usual question-answer session has an element of asymmetry. The one who answers assumes the teaching role towards the one who is curious to know. Excitement and mutual delight come when the former engages the latter as an equal partner and explores the multiple facets of the questions together. The result is an "Aha!" moment. It is this moment that Professor Yash Pal evokes in us when we turn to him with a question. His answers are not just curt and right. He partners with us and makes us enjoy the experience of learning science on the sly! If I may use a musical analogy his answers are not just the lyrics, the *kriti* or the *bandish,* but elaborations of the underlying *raga*, its nuances, its close relatives and such. It would thus be just as appropriate to call him Ustad or Pandit Yash Pal. Read through the questions and answers, and join him in a *jugalbandi*.

- D. Balasubramanian Biologist

I became a young student myself as I read through Professor Yash Pal's responses to questions by young students. Most of the questions were also my questions, and I knew answers to some questions vaguely but Professor Yash Pal's wit and humor made the answers an experience my own experience. As a teacher of literature I know that if I do not share the sense of wonder with the students I cannot teach them,....Professor Yash Pal made me see that this is true of learning in science too.....Professor Yash Pal makes science as enjoyable as poetry. Blake once said that one does not know enough if one does not know more than enough. Every answer that Yash Pal gives sets the student on the path of wanting to know more than enough, with the master as a fellow traveler in discovering the mysteries of this universe. The mystery of the world we live in is still alive for Professor Yash Pal.

- U. R. Ananthamurthy Kannad Writer

FOREWORD

When a champa flower comes off its stem, it spins its way down to the ground. Chandni and sadabahar flowers do no such thing. To explain this difference we will need to go into a wide range of observations and analysis, from the study of shape and design to texture in organic matter and aerodynamics. It is not that we can use the in-flight behaviour of these and other flowers and leaves to connect knowledge associated with

different disciplines; rather, the case is that it is impossible to make sense of the champa blossom's behaviour without letting our mind go across discrete disciplines.

This is the message we get from the answers Professor Yash Pal has given to children's questions over the years, some of which this book presents.

An architect of India's space programme, Professor Yash Pal combines in his career and personality the roles of a teacher and designer of innovative thought and practices. The report, Learning without Burden, written by a committee he chaired in the early 1990s analysed the problem of curriculum load and attributed it to child-indifferent curricula and methods of teaching. In 2004-05 Professor Yash Pal led a vast exercise of social deliberation on the National Curriculum Framework. The outcome of this exercise has begun to unfold, and the required scope of curricular reforms is gradually becoming apparent. It covers a range of long-neglected problems, including syllabus design, textbook style, and teacher training. One of the key messages of the new National Curriculum Framework is that learning must go beyond the textbook and that the child's own experiences outside the school must be put to good use at school. Professor Yash Pal's answers to the questions children send him illustrate how everyday curiosity that children possess can be our guide for teaching them. This is what he calls child-inspired teaching.

His perspective creates the hope that children can become the driving force of educational reforms. Their curiosity will inspire and guide the teacher to connect different spheres of knowledge in ways that the teacher was not taught or trained to do. This collection of Professor Yash Pal's answers to children offers plenty of examples that teacher educators, teachers and parents can use to understand children's minds. Many flaws of our system of education have their roots in our perception of children as empty vessels.

This is an obsolete perception, and though many would deny having anything to do with it, their teaching and other activities, such as syllabus and textbook preparation, are guided by it. To believe that children are a source of knowledge is to take a leap from the past in which our system is stuck, and enter the present where the clarity of the young mind and the urge to make sense of the world await us as the best resource for reform.

KRISHNA KUMAR

DIRECTOR, NCERT

New Delhi, 10 August 2006

ABOUT THE BOOK

This book is a spin-off. It was not planned. It emerged from a joyful engagement with the children of India. This engagement was not formal, in the sense that I was not given a number of topics to teach. It did not take long to discover a number of things children are curious about and what we teach in our formal schools. I already knew that schools normally emphasise acquisition of information in insulated areas. What is outside the formal disciplines is sometimes grouped together as General Knowledge (GK). But that is also largely confined to information gathering. There is little attempt to provide understanding that is built over what the child already perceives, apprehends, knows or

wonders about. This is a result of the regime in which the boundaries between disciplines are sacrosanct and rigid, besides the fact that teaching learning is circumscribed by textbooks and syllabi.

An unexpected experience came my way when I was involved in making the television serial Turning Point. This was done in the company of a number of wonderful producers. There were several occasions when after going through the script I was forced to ask —"So what? What is that small bit of understanding that you are trying to get across?" I do believe that such a demand was new in the Indian programme-making. In addition I started to answer questions from the audience. Pretty soon, there was a flood. I insisted that I would like to entertain questions that children and others in the audience had discovered. The questions kept coming, presenting me with much challenge, learning and enjoyment. There was a time when we were getting three to four hundred letters a day, mostly postcards from towns and villages spread across the country. These questions really tested me, but they also convinced me that true knowledge is built only on observation, perception, wonder and self-learning. I did not provide answers my questioners could easily look up in textbooks. It was clear that the greatest interest lay in the world beyond those books, because the children sensed that their curiosity and confusion was somehow outside the ambit of what could be formulated as an intelligent school question. Most teachers I met seemed to agree with students - they accepted that the questions were not "school" questions. They either infringed the boundaries of syllabus or of the discipline being taught.

At the time I was engaged in this exercise, it was hard fun. But even now, years after that programme ended, young teachers, researchers and students keep telling me that the reason they took to science and engineering was because of Turning Point! When asked about the reason for their remembering that programme, they often turn around and say — "Sir, don't you know, we are the Turning Point generation." While there must be a strong element of courtesy in their remarks, perhaps something special was triggered through the efforts and insight of the production team lead by the executive producer Naazish Husaini I certainly learnt a great deal about the nature of our education in schools and colleges. Primarily, I learnt that we need to make the walls between disciplines porous, that learning f mm life and learning in schools must be connected, that contextual relevance is important to make learning and living more enjoyable and creative.

The Turning Point experience was followed by a sustained interaction through the portal egurucool.com and has been continuing through innumerable face-to face encounters with students and teachers, question-answer sessions through the Internet and in newspaper columns. Most of the questions in this book came to me while I was working on a segment called "Curiosity" in egurucool.com. These questions came to me via the Internet and I responded on-line. 1 kept reminding the letter-writers that I was not a data bank and would prefer to answer questions they had themselves discovered. Even at the risk of repeating some things I have said above it might be useful to quote here from my introduction to the "Curiosity" section of egurucool.com.

"Over the years, I have been asked several questions that have been 'discovered' by children, young and not so young. These questions are seldom of a kind to which straight answers can be found in normal textbooks. Often, they are considered non-school

questions and are not addressed by teachers driven by the need to 'cover the course'. Many of these discovered questions require more than one academic discipline to understand. Over a period of time, a consensus develops that there are two distinct categories of knowledge — one that is acquired in school and the other that is imbibed and internalised through the act of living. Furthermore, a feeling is engendered that these two categories are almost orthogonal, in the sense that they do not, and need not interfere with each other. In my view, this is a tragic consequence of centralised syllabi and regimented teaching. It robs children in many ways. It diminishes their status as discoverers. It reduces the joy and excitement of learning. It reduces the applicability of what is learnt in school

Let me first say a few words about the nature of questions and answers I would deal with. Do not take the answers as the truth. I am not here to dispense truth. Or serve as a data bank. Let us start a process of exploration and joint understanding. I do not like quizzing contests. I will never be a party to one. The fun of understanding is internal. It is a reward in itself. We do not need to be in a race to prove that we are faster than others. Let us leave that to the sports arena, if you like.

Some answers may be tentative and could be improved and enhanced through interaction. We will also make tangential connections with interesting things and happenings around us. Occasionally, we shall discover that the "dry stuff" we learnt in school is useful not just for passing an exam; indeed, it makes us capable of understanding things that are considered rather sophisticated, and enables us to make useful and acceptable contributions to existing knowledge. The aim is to enhance the fun of learning; or more than just the fun- the joy of learning! So let's roll" [1]

This book is largely based on the questions that came to me while working on the Curiosity section of the portal egu.nicool.com.

Preparation of this book has been done in collaboration with Dr. Rahul Pal. He is 34 years younger and impatient with false claims of clarity. We have had occasional quarrels over expressions to be used. He often thought that I tend to be sloppy. His knowledge of science is fresh, mine is a memory. His comments on points related to life science and chemical sciences have won out. On occasions, he tended to write like a scientist presenting a paper. I preferred play and was careless about absolute accuracy. It is possible that the reader may not notice the debris of our quarrels. This is because they were quiet, productive battles without much bloodshed. But I would like to assure everyone that I could not have done this alone.

Some explanation about the organisation of this book might illuminate our bias. We did not sub-divide the matter into subject areas, because we are not in the business of fitting into some one else's definition of walls between disciplines. We have put in the questions in the order they came in and we have not defined prerequisites for reading and understanding the answers. We have also refrained from making a separation between questions from children and those from adults - of which there are quite a few. We seem to have a bias for childlike questions. Though there was no specific programme for any filter of this type, it seems to us that once you frown upon discipline-imprisoned questions and keep reminding the correspondents that their discovered questions would have preference, a childlike character emerges automatically. We have provided an Index at the back of the book, listing keywords, and all questions have been catalogued in the

Contents. It is not essential that all readers should read all the answers at one go. Any process of entangling with this book might be rewarding. Indeed, I keep dreaming that a whole curriculum for education could be based on the discovery of questions by learners! Discovering what is to be learnt and learning itself could become a cooperative activity of students and teachers.

This book may not be the end of our exercise. We have subsequently accumulated a large amount of material while responding to questions through newspaper columns in the English, Hindi and Malayalam press. If a readership develops for this book, others would follow.

YASH PAL

How the book happened ...

I could not imagine growing up with a different set of parents. Perhaps no one can. I don't know. They emanate effusive warmth, have always acted with a gentleness that is without boundary, and have lived by an emotional generosity that permeates the littlest of acts. And, if that were not grace enough, my father suffuses our home with an intense and invading curiosity. When things happen, or when even things just ARE, they need to be understood. He finds wonder everywhere he looks, and he gently prods us to look again. His curiosity is unbounded, unhindered and unrestricted, and unmindful of time or circumstance.

Helping my father put this book together has been a bit of a challenge. I frequently have trouble organising words in a sentence, and letters in a .word. He, on completely the other hand, is wonderfully expressive, in both the written and spoken word. To suggest changes in something he's written is, to me, an affront. I do realise that the modifications I have made may have occasionally subtracted from the romanticism and colour my father invariably invokes, and may have made things a little clinical. I have intervened only when I believed (perhaps naively) that clarity was being compromised. To his eternal grace (and possibly, his paternal indulgence), he rarely corrected my corrections.

RAHUL PAL

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I want to thank Vivek Agarwal, the then CEO of The Learning Universe, for allowing me to use my answers on egurucool for this book. Needless to say, I also thank all those hundreds of children who kept showering me with their curiosity.

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I am truly thankful to them all for their help and cheerful cooperation, without which this book might not have seen the light of day.

YASH PAL

1. Does sunscreen really protect skin?

Perhaps it does, to an extent. Skin cells produce melanin when exposed to sunlight, which determines the colour of the skin; in darker persons, the melanin production is more efficient. Perhaps a layer of melanin then protects the skin cells from damage or severe sunburn. Sunburn is caused when the skin cells get an overdose of sunlight. *The* first stage is the suntan that lighter-skinned persons seek so passionately. But if exposure is for long durations and high in ultra violet, as at high altitudes, the skin cells swell and the skin can become red and sore.

In our country, the desire is not so much to acquire a tan because most of us are already so well tanned. Instead, a lot of face and skin creams are sold, promising fairer looking skin. The need therefore is to reduce the production of melanin. This could be done to a small extent by reducing exposure to sunlight and, specially, to the ultraviolet end of its spectrum. This might be achieved by lacing any old face cream with tested amount of a powder like titanium dioxide. Some of the light might be scattered away and some degraded down to more benign wavelengths through absorption and re-emission processes. Less melanin is formed and the person becomes fairer! I personally think that melanin is a marvellous substance and that black is not only useful but also beautiful.

Like many of my answers, this too is only an educated guess. Do not blame me if you fail after giving this answer in an exam on this topic. I appreciate your curiosity and urge you to proceed further than I have been able to do. I only share a way of thinking - not necessarily the truth.

2. How can a train be stopped by simply pulling a chain in the compartment and how is that compartment later identified?

I have never examined the actual mechanism by which the pulled chain stops the train, but I can guess what its essential elements would be. My guess is the following — If we have a cylinder in which we maintain low pressure, through suction or whatever other mechanism, and if we have a piston in that cylinder, this piston would be pulled in towards the low pressure end with substantial force. This force can be used to restrain a set of strong springs that would otherwise squeeze the brake shoes onto the rims of the train wheels. To apply the brakes, all we need to do is break the vacuum by letting in some air into the cylinder; the springs will then do their work. The actual mechanism might be somewhat different, but the principle must be something similar. If we had total vacuum on the evacuated end of the cylinder, the force on the piston would be about a kilogram on every square centimeter. A piston surface of 10 cm. radius would exert a force of over 300 kilograms. It may also be mentioned that each coach does not need its own pump for creating a low-pressure reservoir. Since individual compartments are inter-connected, the low pressure could be generated in the engine itself. Also, you do not need a very high vacuum; even a slight lowering of pressure is enough to provide sufficient force. Incidentally, some trucks also have such vacuum brakes.

You have also wondered about the manner in which the guard identifies the coach in which the chain was pulled. It could be a rather simple mechanical coupling that pushes out an accusing flag from the side of the train.

3. I've often noticed that when I'm working on my computer and I place a finger between the computer screen and my eyes, I see a somewhat translucent double image of my finger. How does it happen?

The observation arises from the fact that you are blessed with two eyes. Close one of your eyes and you would see only one, non-translucent Image. When you focus both your eyes on the screen, the brain takes the two Images and combines them into one picture. But it cannot simultaneously combine the images from an intermediate object on which it is not focused. So you see two images and they are displaced with respect to each other. The line from each eye to the finger is different because of the slight distance that separates the eyes. The translucence of the images arises from the fact that the light of the screen coming In the direction of one eye is not as completely obstructed for the other eye. You would also notice that when you close one eye and then the other, the image shifts. This is called parallax. Modern cameras use this to determine the distance to an object and automatically adjust the focus of the lens.

4. I have read that when white light passes through a prism, it separates into 7 colours. Why doesn't the same thing happen when white light passes through a simple glass block? What makes a prism special?

I am sure you know that light can be considered a wave of electromagnetic energy. As for any wave, the wavelength of light can be defined as the distance between two neighbouring crests of the wave. The colour we perceive or detect depends on this wavelength. Red light has a wavelength almost twice that of violet. White light is a superposition of waves with intermediate wavelengths falling between (and including) violet and red. What a prism does is to destroy this superposition - rays of light of all wavelengths do not fall on our retina on top of each other. Your question in essence asks why this should happen only when a prism and not a flat block of glass is used.

When a light wave enters a flat block of glass, the speed of light reduces, with the amount of reduction being more for shorter wavelengths. This reduction of speed of wave propagation does not produce any change in the direction of motion if the wave front hits the surface flat on (that is if the light ray hits the surface normally). On the other hand, if the wave front hits the surface at an angle, there would be a bending of the light ray. This bending is precisely reversed when the light ray re-emerges from the other side of the glass block, provided the emergent edge-face is parallel to the incident edge-face. The direction of bending is different for different colours in transition from air into glass. It also depends on the angle of incidence on the glass. However, on emerging from the glass plate, all colours are again superposed, running parallel to each other and therefore, there is no dispersion of light - in other words, no breaking up into different colours.

On the other hand, when we use a prism, because of non-parallelism of the glass faces, the angle of light incidence is necessarily changed (and changed to a different degree for different colours) while exiting from the glass surface. There is therefore no longer an exact superimposition of different colours after emergence. That is why we see white light split into its constituent colours that emerge at slightly different angles.

5. Will the oceans ever become "extinct" due to deposition of decayed particles on the seabed?

Over long (or "geological") time scales, the oceans and mountains are being continuously transformed. For example, a few hundred million years ago, the landmass of India was in the southern hemisphere. There existed a big ocean where most of India is now located. There were no Himalayas to our north. This awesome mountain range was created slowly when India collided with the Asian continent. This collision is still in progress; India is still moving north-north-east at a rate of about 5 cm a year, with the landmass burrowing under China. (In the last million years, the displacement would therefore have been more than 50 kilometres; the birthplaces of gods and early humans in our land must have moved through a distance of this order or more!). All over the world, sea fossils are found on tops of high mountains, showing that nothing is permanent on these time scales. The Earth is continuously transforming. Large oceans have mid-ocean ridges where matter comes out from deep inside the Earth as hot lava, sometimes making islands that rise above the sea surface. Continuing eruptions spread the out-coming matter that is transported along the ocean bottom to edges of continents where it is subducted back Into the Earth's mantle. Some of such subduction zones lie along the West Coast of North America and along the eastern edge of Asia. Thus, there is continuous change; what will happen in millions of years can only be surmised.

Dead matter arising out of living things does change the morphology of the oceans. For example, many coral islands and reefs are nothing but accumulations of coral skeletons; these organisms grow at relatively shallow depths so they can utilise the penetrating sunlight. Coral mountains sticking out high above the sea surface cannot exist because coral needs both seawater and sunlight. Though qualitatively significant, this phenomenon also rides on the much larger basic elements of the drama that keeps altering the surface of the Earth. If there were no volcanoes on the sea floor, there would not exist any isolated hills reaching out from the depths of the ocean around which we have so many beautiful coral reefs - no Lakshdweep, Mali, Andamans or Hawaii.

Yes, transformed organic matter does produce some significant changes, but geologic changes still remain supreme.

6. Our eyes cannot detect ultra-violet radiation, a capability found in bees. How would the Sun appear to bees?

Bees also see in the "visible" (as defined by the capability of human eyes) part of the spectrum. Their vision towards the red end of the spectrum is poor, to the extent that what appears red to humans would appear black to them. They certainly can see much further beyond the violet, towards shorter wavelengths. That they can differentiate between different colours has also been established. The Sun would be visible, but the hues would be different. The ability to detect ultra-violet must confer some biological or evolutionary advantage. I do not know whether the bees derive aesthetic pleasure from the abundance of illumination during the day. If they do have a name for the light that comes through upon scattering from air molecules, something that gives us our blue skies, their sky would be rather "ultra-violetly" blue! On the other hand, their relative insensitivity to red would deprive them of orange sunsets or the red globe of the setting Sun.

In addition, bees do share with many birds a faculty that we do not have. This is the ability to detect the plane of polarisation of skylight. Polarisation is also the result of light scattering and its degree and direction depend on the angle between the direction of seeing and the direction of the Sun. Thus, the direction of the Sun can be determined even during a cloudy day, if a small pocket of the blue sky is still visible; clearly, this capability would be extremely useful for navigation.

As mentioned above, it is definite that bees are quite sensitive to ordinary light. When they return to the hive after detecting a source of food, they communicate the information about the find to other bees through an intricate dance, wherein the direction of the find is indicated with respect to the direction of the Sun at that time. If the hive is darkened and then artificially illuminated with a light bulb, the position of the bulb is taken to be the direction of the Sun, and the dance is modified accordingly!

7. What makes dog man's best friend? Why do they behave like humans do?

What an amusing statement! I do not think one can say that dogs behave in ways similar to humans. They have been domesticated over a long period of time and we get along because we are somewhat complimentary. They are dependent on us. They have some capabilities that are much superior to ours - for example their sense of smell. They, like many animals, have deeply ingrained territorial instincts and therefore can be trained to guard us from intruders. They are (or can be trained to be) more affectionate towards us than even their own kind. It has to be recognised that what we call "training" is based on a system of rewards for behaving the way we like, and includes sharpening the faculties that are useful to us.

8. How do the northeast trade winds bring rain to Asia?

I suppose you are referring to what we otherwise call our winter monsoons. These winds come from the northeast during winter months in the northern hemisphere. The basic driving force is similar to that for the southwest monsoons that we get during summer - the winds travel from colder regions to hotter ones. Winds become laden with moisture after travelling long distances over the sea. In our case, most of the moisture is picked up over the Bay of Bengal and the southeast coast of the country gets the most rain at the time. For the east coast of the Asian continent, the winds pick up moisture over the Pacific Ocean.

9. Why do we have a pair of kidneys when one can stay perfectly healthy on one kidney? Does this constitute spare capacity, in case of failure? If so, why has evolution not provided additional copies of other organs as well? Alternatively, will evolutionary pressures cause the elimination of one kidney in the future? Are both kidneys used at the same time?

I am no expert in this area, but it has often been found that a spare kidney is a good idea. I think both kidneys are used in the normal course, even though, as you rightly mention, it is possible to live a reasonably normal life with just one; this fact makes live kidney donations to compatible recipients possible.

We do have lots of active "spares" in our body; eyes, ears, hands and legs (which all exist in pairs) come to mind. It's clear that survival is possible (admittedly with less efficiency) upon loss of one of the pair. Different survival strategies have evolved in other organs to deal with adversity. For example, more than 80% of pancreatic tissue needs to be destroyed before a drop in insulin production is seen (indicating a tremendous spare capacity). Also, adult liver tissue retains the capacity to regenerate after destruction due to injury or surgery. Two hearts might have been a good idea, but the one we have is good enough to last if only we live properly - eat responsibly and exercise adequately. Two brains might have been problematic - all of us would be schizophrenic! On a more serious note, you are perhaps aware that biotechnologists dream of one day being able to grow synthetic organs for transplant purposes, forever ending the scarcity that deprives so many.

I do not know what the future holds. I would just like to re-iterate, however, that if we treat our bodies well, they are designed to last us a lifetime!!

10. Why is ice less dense than water?

Ice has a crystalline structure. In a crystal, the atoms are arranged according to a specific design, the shape of which is determined by the mutual forces between the constituent atoms and molecules. The lattice of the crystal has an architecture, much like the architecture of buildings made of bricks. We know that all the bricks used in building a house can be stored in a volume much smaller than that of the house. The "density" of the house is much lower than that of bricks.

11. Why is sunlight so hot and moonlight so cool?

The reason is very simple. The Sun is millions of times brighter than the Moon. All of the Moon's light is just scattered sunlight; it does not emit any light of its own. The fact that we can discern objects in moonlight is due to the remarkable capacity of our eyes to adjust to extremely low levels of light. Of course, moonlight differs from sunlight in its basic character as well; it also depends on the scattering properties of the Moon surface.

12. My grandmother had a short fourth toe. My mother does not share this characteristic, but I do. Why is that?

Your grandmother inherited her genes from her parents and your mother from hers. Both the parents are involved; there is a two-ness to genetics. Characteristics such as digit length are probably inherited in a "dominant" fashion (see below). The size of a particular finger is therefore not determined by averaging the influence of both parental genes; the finger can either be short or long. The final outcome (or phenotype, the physical expression of genes) depends on statistical chance.

The problem you have presented is concerned with the field of Mendelian genetics. A monk named Gregor Mendel was much taken with problems of inheritance; he used pea plants, and studied traits like seed shape and flower colour to elucidate the laws of inheritance. He studied this using various generations of peas. After years of study, he arrived at a basic, working understanding, at a time when even the concept of the gene

was still many years away. His work, unnoticed for almost a century, is now considered as one of the greatest discoveries of science. Let us now come to the specific question you have asked and analyse it using the ideas developed by Mendel. As far as possible, I shall avoid using the jargon of the science of genetics.

Let us assume that the genes responsible for a short fourth finger appear in two forms, F (the "dominant" gene) and f (the "recessive" gene). These elements are found in pairs, with one gene coming from each parent; four possible combinations of pairs can therefore exist. F-F, F-f, f-F and f-f. The way it works is this: the presence of F gene would ensure a finger of normal length, irrespective of what its partner might be. This means that a shortened finger can, only be the result of an f-f combination of genes. If your grandmother had the pair f-f and your grandfather the pair F-F, all their children would be F-f, and so would have a normal-sized fourth finger. This means that your mother would not have a short fourth finger even if your grandmother did. If your father also had a gene combination similar to that of your mother, namely f-F, you and your brothers and sisters could be born with combinations F-F, F-f, f-F or f-f. The probability of the shortened finger combination (f-f) is therefore 25%, which is considerable. I do not know if any of your brothers and sisters also has a similar condition. If, on the other hand, your father had an F-F combination of genes, you too would have escaped this condition (like your mother), because the possible gene combinations would then have been F-F, F-f, f-F or F-F - with no possibility of an f-f combination arising.

The assumptions 1 have made may be too simplistic (many traits may be controlled by more than one gene), but still serve to illustrate how genes work to control the expression of certain physical traits.

13. What makes evaporation different from boiling, in terms of the latent heat of vaporisation?

How is the boiling point of water dependent upon atmospheric pressure?

It might be useful to take both these questions together. The heat required to convert liquid water into a gas is referred to as latent heat. It represents the energy required to pull molecules of water away from each other, overcoming their mutual attraction. At low temperatures, only a few molecules manage to escape, those whose thermal velocities are at the upper end of the energy distribution of molecules in the liquid. This is what causes evaporation. As the temperature is raised, more and more molecules acquire energies sufficient to escape from the liquid, and therefore the rate of evaporation increases. When a temperature that is high enough for most of the molecules to escape the liquid is reached, the liquid begins to boil. The temperature, which is after all nothing but a measure of kinetic energy of the molecules, cannot increase any further, because any increase in the energy of the molecules leads to their escape from the system. At this point, heat just serves to overcome the mutual attraction of the molecules. But there is more to this drama.

The poor molecules attempting to escape the embrace of others in the liquid have to face the pressure of the atmosphere above, including that exerted by their companions that escaped before them. This pressure keeps them close to the liquid surface and many of them return. If, on the other hand, the pressure outside is low, the molecules escape to

greater distances. Lowering the pressure enables even those molecules to leave that have not yet attained velocities that would be considered high enough at normal pressure. Thus, at low pressure, the liquid begins to boil at lower temperatures, because molecules that are not very energetic can also overcome the barrier. This is the reason that the boiling point of water decreases at low pressure and, conversely, is raised when the pressure is increased. The latter effect is exploited by pressure cookers; higher pressures ensure that water attains temperatures well beyond 100°C without boiling, thereby hastening the cooking of food.

14. When entering a parallel glass plate, how do light rays "know" that when they emerge from the other surface they must join up? What do they do to remember this?

The rays or the wave do not have to "think" about what to do next. The bending that occurs on entering the glass plate is exactly reversed while emerging, In deference to the same law that made them change direction while entering. Except when incidence is vertical, the light beam emerges displaced and this displacement would depend on the wavelength.

15. Energy can be transformed from one form to another and mass can be transformed into energy by nuclear fission. Also, every living form is considered to be a bundle of energy. Can mass be therefore referred to as a form of energy?

Yes, it certainly can. If only it was possible to pay your electricity bill for a year by sending the Electricity Company an equivalent amount of mass, say a tiny grain of sand!!

16. Do ghosts exist?

Only in our mind; some might say, just like God. You have to define the word existence. Fables and poetry also exist. So do all kinds of terrors. Also music and songs. But ghosts that would need food and water and have babies - that is going too far.

17. I have heard somewhere that the radius of the Earth can be calculated by observing the sunset at the seashore. How is this possible?

I think you might be right. Let us take a simple case. Imagine you are located at the equator of the Earth and it is mid-summer. You note the exact time the Sun sets for you. You ask a friend living a distance D due west of you to note the time when the Sun sets for him. If the delay in his observing the Sunset is y hours then the circumference of the Earth C is given by $C = (24 \times D) / y$

The justification for this simple equation is: If a point on the Earth moves through a distance D in y hours, then the distance it would move in twenty four hours, must be equal to the circumference of the Earth.

If you are not on the equator, some modification of this equation may be required, but the principle remains the same.

18. If I am standing on the North Pole and start walking and reach the South Pole, will I be standing upside down? When I am looking at the sky, am I actually looking 'down'?

I know it is hard to comprehend, but "down" is most naturally defined as the direction in which we would fall, were we to lose balance. For us on Earth, this direction is towards the center of the Earth. Yes, on the South Pole, your feet will be pointing towards the feet of your friend standing at the North Pole. Your heads will be pointing in opposite directions. You would see different stars; at the North Pole, the Pole star would be overhead, whereas at the South Pole, you would never see the Pole star. On the other hand, if you are in orbit around the Earth (where the force of gravity is not felt), you can define your "up" and "down" at will, or even do without this unnecessary definition.

19. Why do good conductors of electricity like gold not show super-conducting properties?

It is difficult to properly explain the phenomenon of superconductivity in simple words. I mean it is difficult for me, though there must be others who can do it rather well. But let me address the specific question that has been asked.

Superconductivity implies that electrical resistance of the substance is zero and it has perfect diamagnetism, with zero magnetic fields in the interior. Resistance is due to interaction of the conducting electrons with the lattice. This resistance goes down for all conductors as they are cooled. This happens gradually and monotonically, except for some conductors when the resistance suddenly drops to zero and, simultaneously, the magnetic field is expelled from within the conductor. These materials are referred to as superconductors.

The theory of superconductivity shows that a pair of electrons can have an attractive interaction between them via the lattice. One can understand such an attractive interaction between two negative particles in the following way. Presence of an electron near the nucleus of the lattice leads to an attractive force that distorts the lattice. Before the electron passes by and before the lattice springs back to its normal position, a second electron is drawn into the trough. It is through this process that two electrons link up. Two such electrons tied together through such an Interaction then form a pair that transition to a state of opposite electron spins. Such pairs, called Cooper pairs, congregate to form a boson condensate for which interaction with the lattice ceases. This condensate can then move freely under the influence of an electric field, i.e., without any resistance. This is superconductivity.

It is argued that metals like gold and platinum have a high conductivity because the electrons have a weak interaction with the lattice. That means less lattice distortion. This then implies that the mediation of the lattice is also less effective in producing Cooper pairs. No Cooper pairs means no coherent condensate of electron pairs and hence no superconductivity!

I am aware that in the above explanation I might have used words and concepts that might be rather opaque to some of you. I do not like doing that. Perhaps some of you can help to simplify the answer further. I would welcome it.

20. Why does the Sun appear bright in the afternoon and mild in the evening and morning?

The rays of the Sun have to pass through the atmosphere to reach the Earth's surface. Looking vertically up, the mass of the air column over each square centimetre at sea level is about 1,030 gm. per cm^2. (This is the amount of matter a particle or a light ray coming from outside in the vertical direction would encounter before reaching sea level). However, when looking towards the horizon, the thickness of the air column that the particle or the light ray has to go through is much greater. In other words, the sunlight has to pass through much greater amount of air to reach the Earth surface at dusk and dawn. Air molecules scatter light. Dust and aerosols also scatter and absorb the Sun's energy. The increased absorption in the mornings and evenings makes the Sun less hot and less bright. You know, of course, that the apparent change in the observed colour of the Sun between mid-day and dawn or dusk is due to preferential scattering of different colours of the sunlight. The blue colour of the sky is due to the scattered light of the Sun; blue light scatters far more than the other colours in the spectrum. The Sun appears orange at sunset or sunrise because most of the blue and green have been taken away by scattering during long traversal through the atmosphere in the horizontal direction.

21. What is the difference between "neutral" and "ground" in an electrical connection?

As its name suggests, the ground wire is connected to the ground; the neutral is not. The ground wire ensures that in case of a leakage, an appliance does not acquire a voltage that might cause injury or malfunction. It appears that there is no need or separate identification of the live and neutral terminals when you are dealing with a single phase of alternating current. You just need an incoming wire and an outgoing wire to complete the circuit. But many homes and establishments are served by three phases. In that case you would need three separate pairs of electric cables, in other words a total of six cables. On the other hand, if you make one of the cables as a common neutral you would need only four cables, resulting in great saving. You would have noticed therefore that in your switchboard serving a three-phase supply, there are four cables coming in and one of them, called the neutral, is connected to all your appliances and light fixtures.

22. What is DNA finger printing? What are its uses?

DNA exists as strands of bases that carry genetic information specific to each living thing. The sequence of bases of DNA in each of our cells is the same, but differs from that of any other living thing except possibly an identical twin. This difference makes the DNA break at different places when certain proteins called enzymes are added to it, resulting in smaller DNA fragments of different sizes. These fragments migrate at different rates in an electric field, resulting in a unique pattern; this pattern is referred to as a DNA fingerprint.

Our DNA is inherited from our parents. Some parts come from the father and some from the mother. DNA fingerprinting can help identify parentage, since a son or daughter would always exhibit a pattern identifiable as coming from both parents. DNA fingerprinting analysis is very useful in forensic science; from a single hair or a tiny spot

of blood, it is possible to prove the innocence or guilt of a murder suspect. Similarly, it is also possible to identify human remains after violent accidents have caused disfigurement.

It has been suggested that in the not so distant future, a DNA fingerprinting profile of the individual will have to accompany applications for an ID card, a bank account and a driving license. Human right groups say this type of "genetic profiling" constitutes an invasion of privacy. As with a lot of new technology, DNA fingerprinting also has *a* potential for abuse.

23. What constitutes the Earth's magnetic field? What is its origin? Doesn't the intense heat at the centre of the Earth affect the magnetic properties?

There is no bar magnet sitting at the center of the Earth; you are right in suspecting that any such magnet would surely be destroyed by the intense heat at the center of the Earth. However, the Earth's magnetic field arises precisely because the inside of the Earth is hot enough to melt iron and there is iron in the core of the Earth!

The heat inside the Earth (generated as a result of decay of radioactive elements at the core) produces convection cells which transport liquid conducting material upward and then down again, very much like what happens when we put a pot of water to boil. The motion of the conducting material, in rather regular loops along with the rotation of the Earth, produces a dynamo effect - in other words, loops of electric currents. The Earth's magnetic field is supposed to be a result of these currents. So, we need the following conditions for a planet to have a magnetic field:

> A heat source - which is provided by the decay of radioactive elements - to produce convection.

> Conducting liquid in the core - which we do have.

> A rotating planet - a condition that is also fulfilled.

24. Why is the sky dark at night? Why is there no light due to diffraction from the Earth's surface?

I suppose you are asking why light from the illuminated side of the Earth is not scattered by the atmosphere to a significant extent, so as to illuminate the side darkened by night. This does happen at dawn and dusk; the land is bright even before sunrise and after sunset. But as the Earth turns and the Sun dips further away, this light disappears. Our atmosphere does not extend very far - less than a hundred kilometres. So there is nothing above us that could receive the scattered light from the sunlit side. The situation is somewhat different near the Polar Regions. During the summer months, the Sun does not dip much below the horizon and the night stays illuminated by either direct or scattered light. Therefore, mid-summer nights are never pitch dark at the poles; sunlight or a scattered twilight keeps the land (or the sea) bright.

When I first read your question, 1 thought you were referring to something known as the Olber's Paradox. Simply stated, the paradox is: Why is it dark at night? If the sky is filled with galaxies and stars all the way to the end of the Universe, there should be a star no matter where you look. It follows that each point in the sky should be as bright as a

similar sized point on the Sun. Why is this not so? The basic explanation is provided in terms of the expansion of the Universe. The light from stars at cosmological distances is reddened to extinction (the so-called "red shift"); it has fallen below visible range. In a way, this is the explanation given, in the Big Bang cosmology, for the Cosmic Microwave Background radiation. The initial "fireball" of the Big Bang was extremely hot. As the Universe expanded, this radiation cooled due to the Doppler Effect. Cooling of radiation implies shifting to longer wavelengths. This red shift has moved the wavelengths of the initial radiation into the microwave region. Such radiation has actually been detected and is popularly known as the Cosmic Microwave Background.

25. All of us believe that life can be found on a planet only if there is water on it. But aren't we being too narrow in our thoughts? Does not nature have the capacity to produce living beings that can survive on a compound other than water? If we assume that such creatures exist, they would probably be thinking that no life is possible without their special compound (and not water).

I agree. We are extremely parochial in our thinking. Not long ago, we humans believed that the whole Universe was created for us. While appreciating the enormous diversity of living things, we thought that all the other living things were ultimately meant for the enjoyment of and exploitation by, humankind. Indeed, many people still believe this. Even after the Theory of Evolution and realisation of our kinship with everything that is alive, our parochial way of thinking remains.

This is explained by the fact that wherever we have looked, we have found only one example of life; every living thing we have encountered lives on the basis of intelligence written and programmed with the same genetic alphabets. It is easy to lapse into a mode of thinking that this is the only possible form of life. You have rightly questioned this version of human self-centeredness and parochialism.

We know, of course, that hydrogen is the most abundant element in the Universe. If by using hydrogen, carbon and oxygen one can evolve blueprints for self-replicating systems (as we very well know is quite possible), it is natural to think that the most abundant life forms would be those that are evolved using these abundant raw materials. This certainly does not mean that other life forms would be the same or even similar to us. Also, I doubt if one can theoretically prove that nothing radically different is possible. Even with a deep understanding of all the evolutionary forces that impact the generation of species, I do not believe that a hypothetical super intelligence could have, a priori, predicted or imagined the diversity of the Earth's life forms.

You would know, of course, that some science fiction writers and serious "futurologists" have not ruled out the possibility that a "living" community of thinking computers might emerge at some future point in history! It is amusing to imagine that, several million years from now; future students (with embedded silicon brain chips?) of archaeology might consider the human species as a step in the evolution of such a community!

Let me in the end say that I am not intelligent enough to rule out the possibilities that have occurred to you. There might be other modes of self-replication that we can't even imagine.

26. I recently saw an article somewhere stating that scientists had redefined the value of pi. Is it true? Could you explain how it was done?

I believe we are not talking about redefinition of pi but a calculation of pi to the largest number of decimal places. People are searching for some repeating patterns in the decimal digits of this transcendental number. This work is being done with the help of powerful computers and I suppose what you have heard about is determination of the value of pi to an extremely large number of decimal places.

27. How does cooking happen in a microwave?

Passage of microwaves through food results in increased agitation of molecules. If we can increase the amplitude of the random movements of molecules, we are doing nothing but heating the food. But how do microwaves increase the agitation? At microwave frequencies, the alternating electric field of the radiation interacts with the electric dipole moment of water molecules, making them vibrate faster. The absorption length of the microwave energy is long, meaning that not all energy falling on a chunk of cooking food gets absorbed while traversing through it, It also means that for microwaves, in the simplest approximation, there is no inside or outside of the food chunk; heating occurs all through the body of the food. That is the reason you do not get a crisp surface on the outside, as you would in normal cooking where the heat has to travel inwards from outside. When you cook a big chunk of raw food in a pan on open fire, the surface might become tastily crisp, while the inside might remain relatively raw.

Also remember that a microwave oven is an enclosure whose walls have excellent reflecting properties. Therefore, the fact that little microwave energy is absorbed upon initial traversal through the chunk of food does not mean that the rest of the energy is lost; the reflective metallic walls of the oven bounce the microwaves back and forth to ensure repeated interaction with water contained in the food. Ideally (in a "perfect" oven), the only energy loss would be via heat transfer to the food inside.

28. What is the concept behind Zero Point Energy? Can it be used to propel a spacecraft to the speed of light?

I find some of your questions come from the science fiction movies you see or books you read. These movies or books borrow a lot of terminology from the present day science and then embark upon their own flights of fancy. This is enjoyable and often very useful. But all the romance depicted there cannot be taken seriously. Let me see if I can make the basic ideas behind the term Zero Point Energy somewhat comprehensible. Some fundamental concepts are involved here.

When you take some material (say a simple gas) and cool it down, you would progressively reduce the thermal energy of its molecules. The energy content would continuously reduce while the gas turns into liquid and then perhaps a solid. You go on cooling till you approach a temperature close to zero degrees Kelvin. You cannot go below that temperature. This temperature is defined as Absolute Zero because all thermal motion comes to a stop. The fact that you cannot cool the sample any further inversely

implies that you cannot extract any more energy from it. It is another matter that Absolute Zero may never be obtained. Here other considerations come into play. These derive from quantum statistics and the Uncertainty Principle. If the particles of the material under consideration are identical bosons (in other words they have integral spins), they can all be in the same state. The same state implies that they can have the same position and momentum and there is a possibility of forming a new state of matter known as a Bose-Einstein condensate. Such a state has been realised during the last few years by using sophisticated cooling and confinement techniques. Of course, we still have to honour the Uncertainty Principle - this manifests itself in intriguing and interesting ways that we cannot consider in this brief and rudimentary discussion. But let us now move to the exact question that had been raised.

For bosons, there is no Zero Point Energy. But now consider identical particles with half-integral spin. Such particles are subject to different statistics. This is controlled by the Pauli Exclusion Principle which states that only one particle can occupy a well-defined quantum state. If one particle is sitting in the lowest energy state, there is no room in that state for another one coming in with the same spin and angular momentum. It will be asked to go to the next higher energy state, no matter how low the temperature of the system. For example, an electron in an orbit of zero angular momentum around a nucleus will welcome another one of its kind only if it has the opposite spin direction. After that, there is no more room in that energy state. If we were to think of a gas of neutrinos cooled to a temperature of absolute zero, they will not all lie in the lowest zero energy state because of this "untouchability" principle! Many of them will have to remain in higher energy states. Depending on the density of the neutrino gas, the Fermi energies of some of these particles could be significant. This is the energy we call the Zero Point Energy. I do not see how this energy can be used in any significant way, let alone accomplish the feat of accelerating a spacecraft to high velocity and energy. That imaginary concept is best left to the domain of juvenile science fiction stories.

29. We see only one face of the Moon because the period of its rotation and that of its orbit around the Earth are the same. But why should it be so?

You are right in wondering about this coincidence. In fact, it is an exact match. Both these periods are 27 days, 7 hours and 43 minutes or, to put it in more compact language, 27.32 days! Science does not like such accidents. There must be a reason why the periods are the same. Let us explore this question.

You all know about tides. They are caused by the fact that the Moon-ward side of the Earth experiences significantly greater gravitational attraction than the opposite side. This produces an oval-shaped bulge in the oceans with the longer axis of the oval always pointing towards the Moon - for simplicity we overlook, in this discussion, the smaller effect of the Sun. We usually think of tides affecting only the oceans. That is not quite true. Even the landmasses are affected. They are also a little flexible. In addition, we never think of the poor Moon. It must also be affected by tides, in the sense that, to the extent possible, it must also have a bulge pointing towards the Earth.

A few billion years ago when the Moon was formed, perhaps in a collision between the Earth and another planet-sized object, it must have been spinning much faster than it is now. Also, since the Moon was much closer to the Earth, the tidal force must have

been much stronger. Huge bulges would have been continually forming and dissipating. In relevance to the present discussion, as the Moon spun around, its bulge would have lasted a while after going past the Moon-Earth line. The attraction of the Earth on this persisting bulge would have exerted a restraining torque on the Moon, as if a brake was being applied on its rotation. Such a torque, working over a long time, finally succeeded in assuring that the bulge came permanently in line with the Earth-Moon direction. The restraining torque then disappeared and the rotation of the Moon was synchronised with its orbital period around the Earth. It is easy to see that such a synchronising effect would have occurred even if, in the beginning, the Moon had been spinning very slowly.

It has been found that spin and orbital period synchrony is a general feature of any two large companions. For example, like the Earth and the Moon, Pluto and its Moon Charon also show the same face to each other.

30. Why does a ball travel further when hit with an aluminium bat?

I am rather uneducated about quality gradations of cricket bats. I am sure what you say has a grain of truth. However, I have not heard of Sachin Tendulkar or any other great batsman using an aluminium bat (are there official rules that prevent it? I have no idea!). Nevertheless, let us take an academic look at the question you have raised.

I believe that for every batsman, there is a preferred mass of the bat. This might depend on the strength of his arms and his technique. The size, I suppose, is fixed by regulations. The bat must be much heavier than the ball to ensure that the collision between the two transfers maximum energy to the ball. I suppose an aluminium bat could be made of the same weight as a willow bat. Aluminium is heavier than wood, but that should not matter because the bat could be hollowed out to keep its external shape and size. That done, the only thing left to consider is the loss of energy during impact. Some of the energy is expended to deform both the ball and the bat. We cannot do much about the ball, because it is a standardised entity, manufactured under strict control of size, shape and weight. I am sure some small dents are left on the surface of a bat after a strong hit. It is possible that for an aluminium alloy, lesser energy is absorbed in denting the bat; that would be in its favour. Of course, you cannot avoid the recoil. If the batsman holds on firmly, the aluminium bat might spring back more efficiently than the wooden bat. All this is happening in the split second of the collision. If the time constant of this "spring" were right, the optimal energy would be transferred to the ball.

After this long pseudo-explanation about something I am not even sure of, I would warn you that things might be more complicated. What I have said might not be the "textbook" explanation, correct in all respects. But I do hope what I have said above sets you thinking in the right direction. It would be instructive to talk to a good batsman.

31. How do automobile seat belts work? A sudden jerk to the belt results in heightened tension and an arrest of forward movement, but if stretched gently, the belt offers no resistance.

I congratulate you for discovering this question. It had me foxed for a number of days. I could think of several ways the mechanism of seat belts might be put together and I also knew that this mechanism had to be simple and rather foolproof. I could have gone to a

garage and asked the mechanic to dismantle one of these contraptions. I did not do this because I wanted to work it out on my own. Every time I sat in my car over the next couple of days, I played with the belt for a few minutes till; finally, the solution came to me. I was convinced that the mechanism has to do with a hidden cylinder on which the belt is rolled up. Soon thereafter, I happened to travel in a taxi in Kolkata, in which the cover of the contraption at the base was broken; a quick examination confirmed that what I had visualised was indeed the correct answer to your question. This is as given below

One end of the belt is anchored to the floor of the car. The belt then goes up, passes through a hook and down again where it is rolled around a roller to which it is attached at the end. On the way down, the belt also passes through a clip that is used for locking the belt into a fixture on the other side of the seat. The roller on which the belt is rolled is spring-loaded; it keeps the belt loosely wound up around the roller. When you pull on the belt gently, by holding on to the locking clip, it unrolls from the roller and can be extended to the extent desired. In the event of a strong deceleration of the car (because of sudden braking or a collision) however, the belt is designed to lock in position. The mechanism for this is simple, clever and reliable. The axle of the belt roller can move up and down in grooves at the two ends but is kept pressed down with springs. The retaining rings of the roller have teeth that normally remain disengaged and do not interfere with the movement of the belt. However, in the event of a collision, there is a sudden strong pull on the belt, which exerts an upward pull on the roller. The teeth on the retaining rings get caught by a metallic strip mounted on the housing that holds the roller. As a result, the belt cannot unwind any more and the passenger is restrained from being thrown forward. When the deceleration stops, the roller is pushed down by the springs pressing down on the axle of the roller and, therefore, is disengaged from the strip across the housing, restraining it from unrolling. That is how the restraint comes into play only at the time of a sudden jerk or deceleration.

32. Why does water condense on the inside surface of the car windshield during the monsoon?

The inside of a car whose windows are rolled up can get quite humid because of the moisture in the exhaled breath of passengers (and possibly, from their wet shoes and clothes!!). Also, the temperature inside the car is higher than the outside, thanks to the body heat of the passengers and, sometimes, because of heat leaking into the cabin from the engine compartment. The rainwater cools the windshield and the windows of the car. On touching these glass surfaces, the inside air cools below the dew point and condenses, which often blocks the driver's view.

In modern cars, the windshield is often equipped with embedded heating elements (at the rear) and hot air blowers (at the front). If your car has neither, try opening the windows just a little, to increase the exchange of air; this should help equalise the temperature and/or moisture content and should clear the condensation.

33. Is there any change in period of rotation of the Earth due to change of seasons?

It's an interesting thought. In the normal course of events, there is little effect of the seasons on the period of rotation. However, major climatic change might result in a significant change. Were large quantities of water from the oceans to shift towards the poles and be held there in the form of ice, rotation could be affected? Such a phenomenon could slightly alter the moment of inertia of the Earth; since angular momentum has to be conserved, the period of rotation could decrease (that is, the angular velocity of rotation could increase).

After I had written the above paragraph, a friend drew my attention to the fact that measurement accuracies had reached a level that we can actually see the effect of the increased vegetative mass in low latitudes of the planet during summers of the northern hemisphere. This is because there is much more land surface in the northern hemisphere than in the southern! The moment of inertia of the Earth increases during northern summers!

34. What is the constant of proportionality IB verification of Newton's second law of motion?

I do not know why you are looking for a constant of proportionality in the equation F = m x a. I suppose we could say that the constant of proportionality is chosen as 1 because this equation, in a sense, defines inertial mass.

35. What caused the "red rains" in the state of Kerala?

I can only guess. Just before the occurrence or reports of red rain in Kerala, there were news stories of meteorite bursts from the US. I do not know whether such bursts also occurred in our area. Nevertheless, it is possible that a significant amount of dust was deposited in the upper troposphere by this planetary phenomenon. I am not sure that this was the cause of the observation but clearly something of this sort must have happened. Detailed analysis of the water could have shed light on the source of the red contamination.

36. Why does the south-west monsoon always hit Kerala on the 2nd of June?

It does not always arrive on the 2nd of June. Sometimes, it is a few days early, or is slightly delayed. All the same, it is true that year after year, it's at the end of May or the beginning of June when the first rains arrive in Kerala. The monsoon is a large-scale phenomenon, controlled primarily by the heating of the Indian landmass during summer and the rotation of the Earth. Having said this, I have to warn you that every event during the monsoon is not so well-determined. There is correlation with a large number of other parameters around the world. One of these is the well-known El Nino phenomena which lead to warming of the ocean near the South American coast. Your question, of course, still remains. Why can this mechanism not stagger by more than a week or so?

One has to remember that the Indian monsoon is one of the major energy transporters of our planet. It cannot just dally around and come whenever it likes. Solar input does not change from year to year. The Earth's atmosphere and the oceans also do not alter over

short time scales. Laws of nature remain the same. Perturbations can occur when there is interference with other major transporters of heat.

37. How long does it take for a drop of precipitation (rain) to reach the ground from the clouds?

Meteorology is a fascinating science. It is at once simple and complicated. As water evaporates, vapour is wafted up to colder regions of the atmosphere where it condenses and forms clouds. Drops of moisture in the clouds are tiny, with a diameter of 0.02 mm or less. They are sustained up there due to collisions with air molecules. If the atmosphere were completely still and the cloud base low it would take them up to 10 hours to descend to the surface!

That is not rain. To graduate up to that level, a thousand tiny cloud droplets have to coalesce together to become a reasonable-sized raindrop of 0.2 mm diameter. Such drops can start descending with increasing speed till they reach a terminal velocity when the air resistance becomes equal to the downward force of gravity. For a raindrop of 0.2 mm diameter, the terminal velocity is about 4 meters per second (it would be somewhat higher for a bigger drop).

The time of descent will depend, of course, on the height of the cloud and the size of the raindrop. A drop coming down from a cloud that is one kilometre high could take 250 seconds or nearly 4 minutes!!

38. Why does a chopped apple acquire a reddish tinge?

I knew that this had something to do with exposure of live tissue of the apple to oxygen but I was hazy about the details. So I had to look for an answer, something I do not like to do very much. Apparently, the mischief is done by an enzyme called tyrosinase, some of which is present in all living tissue. It seems that oxygen and tyrosine combine to form melanin. You would recall that melanin is that dark substance which gives colour to our skin. It makes some of us darker than others. So the darkening of apples, as also bananas after being peeled, is due to production of melanin. Living tissue is a very complex thing.

A little more detailed chemistry, for those of you who are interested: A number of changes take place to convert the colourless polyphenols present in fruits to the brown (or reddish) discolouration. These include enzymatic oxidation and polymerisation. The enzyme responsible for browning is Polyphenol oxidase (PPO), also known as catecholase, tyrosinase, and phenolase,

Polyphenol oxidase (PPO) is present in most foods. It participates in the beginning phase of oxidation as it catalyses the change of monophenols to diphenols which are then changed to highly reactive, coloured o-quinones. These then react with other o-quinones, amino acids, reducing sugars, etc., to form polymers that precipitate, leaving the dark discolouration.

Incidentally, I am told that if you put some lemon juice on a freshly cut apple, it prevents darkening to some extent. Try it.

39. Sound is produced due to vibrations, which occur when air passes through the voice box in the throat. Then *why* do different people have different voices?

The air passing through our larynx vibrates our vocal cords. The natural frequency of their vibration depends on their thickness and other physical features. Man-made resonance cavities can pick and enhance various harmonics, with the range of this capability depending on their construction. All drums do not give the same note, nor do all bells. It is truly amazing what gifted musicians can do with the relatively simple sound making system with which we are all endowed. It is clear that the sounds and music made by different individuals cannot be the same. People are not constructed exactly the same on the outside - that is why no two persons look exactly the same; they are recognisable as being different. Similarly, slight differences in the sound-making apparatus (including physical measurements and sizes and shapes of resonant cavities) are not surprising. These variations result in voices that are recognisably different. Another level of complexity arises due to the fact that speaking or singing is also a learnt art. The way we manipulate our tongue or lips also makes a huge difference to our oral output, as does the extent of control over the process of breathing.

40. If the temperature-resisting genes of thermophilic bacteria (which thrive in volcanoes and hot springs) were transferred into the human embryo, will the human race be able to resist the effects of mounting temperatures due to the process of global warming?

Humans live near the polar ice caps or at high altitude and survive in burning desert areas. Therefore, there doesn't appear to be a need to tackle the effects of global warming on humans via the strategies you suggest. The real danger of global warming might be on climate, the submergence of large areas of coastal habitation and a shift in cropping patterns. These changes would probably be manageable if they occurred over thousands of years. If compressed into a few decades, however, the effects on humans and other life forms might be serious. Instead of changing our genetic structure, we have to learn to change our life styles in a way that would ensure a sustainable future for us and also protect bio-diversity. Social solutions might be preferable.

However, I think some transformation of humans through genetic modification is inevitable. A lot of this work might be dangerous, or unethical, and we need to tread cautiously.

41. Electricity is due to the flow of electrons. If the electron is taken away, what happens to the positively charged atom that's left behind?

An electrical circuit is a closed loop. For example, when a battery is connected in a circuit with a resistance, say a lamp, current flows around. Electrons flow from the negative terminal, through the bulb back into the battery through Its positive terminal. Electrons are not permanently leaving the nuclei unclad. As one electron moves, another takes its place. While travelling, the electrons interact with the lattice of atoms in the filament of the lamp, resulting in resistance and the production of heat and light. They do not go and sit there. A simple analogy might be the following — Imagine that we have a ring of a large number of dancing boys and girls. In this dance, the girls are handed over

from one boy to the next, going around in a circle. This 'current' of girls might raise a lot of dust on the way, but at no point would any of the boys be found without a girl next to him. A force akin to the Electro-motive Force would, of course, be needed to keep the girls moving, overcoming the resistance along the path. Unlike the girls in this example, the electrons are all identical and the nuclei will never be able to "tell" that they lost their companion for even a moment and got another one in its place!

There is another fact that has to be understood. In metals, the atoms in crystals live in cooperative colonies. The electrical fields in these crystals are such that some electrons residing therein do not know or care about who their parent nuclei are. Periodic potential of the crystalline structure, coupled with the Paul! Principle and quantum considerations help to understand the sub-division of materials into conductors, semiconductors and insulators. The band gap of the semiconductors that is at the base of all solid state electronics industry also comes out of theory. Band gap is the energy difference between the top level of the valence band and the bottom level of the conduction band in semiconductors and insulators.

42. What is Lorentzian and Euclidean Space-Time?

We all know about Euclidean geometry. This represents the good old familiar space, where three orthogonal axes help to define the position of any point. Here, time is considered to be independent of space and defined independently. It is in the nature of a flowing river and believed to be the same everywhere. This picture had to be abolished when special relativity was discovered and the velocity of light in vacuum was postulated to be constant, independent of the frame of reference of the observer or the source. From then on, space could not be defined independently. It became necessary to think of Space-Time in which Time formed the fourth dimension. This is what one needs when momenta and energies have to be calculated in different frames of reference. This is done through Lorentz transformation and at velocities much less than the velocity of light, the results are the same as in the non-relativistic, Euclidean case.

43. What is the difference between centre of gravity and centre of mass for an object?

Centre of mass is a more general term than centre of gravity. Just think of a system of particles in space orbit. They also have a centre of mass, even though there may not be any gravity there. The centre of mass can be thought of as the point in an object or system of particles where the total mass can be assumed to be concentrated for the purposes of calculating the dynamical influence of any force (and not just of gravity) on that object or system of particles.

There is also the concept of a frame of reference in which the net momentum of all particles of the system is zero. It is useful to analyse interactions of particles in that system. The results can then be transformed into the laboratory system or any other system of coordinates by taking into account the velocity of the centre of mass in that system. You would have noticed that I have used the terms centre of mass and centre of momentum interchangeably.

44. I frequently smoke while riding my two-wheeler. While exhaling smoke through my nose, I experience a feeling of great coolness on my nostrils, almost as if the smoke were cooled by an air-conditioner. Since conditions such as the humidity of the air stay the same whether I'm static or moving, what is the reason for the differing sensations?

Not having tried this experiment, I have no personal experience of the feeling of coolness about which you are so ecstatic. The most likely explanation is that at high speed on a motorbike, any moisture in your nostrils evaporates fast, leading to cooling. Even when you do not smoke, you should get some indication of this. A common experience in very cold climates is the formation of tiny icicles below the nostrils, particularly if you are suffering from a cold. Are you, by any chance, a little allergic to cigarette smoke, making your nostrils a little wetter than normal? Do you smoke mentholated cigarettes? I have more or less exhausted my thinking provoked by your question.

45. Why does the colour of a flame containing different elements or compounds differ?

First let us consider the colour of the light we see. You can think of light as packets of energy, referred to as photons. Large packets hitting your eye give you a sensation of blue colour, while small packets excite a red sensation; those of intermediate size give the sensation of the colours lying in between. Colour is an indicator of the size of the energy packets.

You can think of the structure of atoms and molecules as that of energy ladders with rungs placed at distances specific to them. If you look at one of these ladders, you can tell which atom or molecule it belongs to. The energy packets are produced when the atoms descend from a higher rung on the ladder to a lower rung. The size of the packet would depend on the energy distance between the rungs. Similarly, light packets are absorbed preferentially if they can move an atom or a molecule from a lower rung to one of the higher rungs. Thus, the emission as well as absorption of light quanta, or packets, would depend on the specific ladder shapes, each of them defining the atomic or molecular system involved.

The observations contained in your question can be explained by this analogy. You have only to remember that when you raise the temperature by exposing molecules to a flame, you are pushing atoms to a higher rung on the ladder. Since the rungs are not evenly spaced, the transition distances between them are variable and you can get newer sizes of packets -visualised as different colours. The specificity of the ladder and the atomic species still remains.

The analogy I have given would do for those who do not yet understand atomic structure. It might, however, seem laboured, inaccurate, and incomplete or stretched to those who do understand it.

46. Why does the nose of an airplane generally face the sky when it's in the air?

When the plane is climbing, the nose has to face up. That is obvious. When the plane reaches its cruising altitude, it becomes horizontal; the nose is not pointing up. I think your question perhaps relates to the time when the planes are landing. Why do they have their noses pointed upward at that time? The reason is the following: If the plane tilts the nose down while landing, the front wheel will touch the ground first. The friction on the wheel and the momentum of the plane will produce a torque lifting the back and tilting the nose further into the ground. This would be catastrophic, as airplane landings in the early days of flight revealed. If, on the other hand, the nose is pointed up to ensure that the rear wheels touch the ground first, the resulting torque would reduce the speed at which the forward wheel contacts the ground and thus be beneficial. If you watch bird landings, you would find that they also turn their noses up just before they touch the Earth. I suspect people learnt the right way of doing things by watching birds. There's a lot Nature can teach us.

47. While I was listening to my Walkman yesterday, I found that the battery had discharged. However, after a while, when I switched it on again, it played for a while before discharging once more. This occurred several times. I wonder why this happens.

Dear friend, I congratulate you for asking this question. I have also had this experience, but never thought of thinking it through. After receiving your question I have spent several hours thinking of an answer - without success. I also hit the Internet, but maybe not for long enough. I suggest that we should all try to find a good answer together. One of the explanations that I have been given is this — Dry cells usually behave like that because of accumulation of gas bubbles around the electrodes inside the battery, which dissipate when the battery is kept disconnected for some time.

48. Starlight takes many years to reach Earth. Does this mean that the supernova explosions (as well as other events) which we see at the present time really happened many years before?

Yes, you are right. But as far as any effect that supernova will have upon us, it is only "now". Nothing has changed here because of that happening till we observe its occurrence. "Now" is defined by our clocks and calendars.

49. Why are concrete slabs placed between railway lines?

I suppose you are referring to the sleepers that keep the rails at a fixed distance from each other. The reason for that is obvious. The rails guide the train and they must consistently remain parallel to each other. The spacers to which they are anchored on to the ground used to be made of wood till recently. To reduce forest denudation and to additionally provide longevity, pre-stressed concrete sleepers have become common in recent times. The stones that fill the space between and at the shoulders of the railway lines provide ballast and prevent the rails from misaligning, should the loose soil underneath be washed away by rain water.

50. Where would the poles of a spherical magnet be?

The magnets you are familiar with are produced by aligning the microscopic magnetic domains of a magnetic material. We assign magnetic moments even to individual charged particles whenever they have a spin angular momentum. Nuclei of atoms also have spins. Think of them as tiny magnets that, in a non-magnetised state of the bulk material, are randomly oriented. Magnetisation is a process of alignment. Therefore, for a magnet of spherical shape, the poles would be positioned depending on the manner in which the sphere was magnetised. It might happen, though, that in an irregular- shaped material, and internal interaction between domains could produce localised unpredictability in the magnetic field.

51. Why does Saturn have rings around it?

Saturn is rather unique with respect to its rings. These have been observed at close quarters by the Voyager space probe over twenty years ago and found to be more complex in their structure than was earlier believed. The rings are thin. A spacecraft can go through them without any real danger of collision. They probably consist of water ice and ammonia ice. There might also be some dust and stones. Most particles are small but some might be as large as a few meters. Some of Saturn's Moons are quite close to the rings and might have some influence on their shape and stability. The particles in the rings are essentially independent satellites. It seems that the larger stones act as shepherds to maintain the ring-like structure.

But the question still remains as to why only Saturn should have this fantastic decoration. I do not know whether one can give a definitive answer. A satellite, planet or Moon might have broken up in its neighbourhood and the debris spread out as a ring. Could there have been a large comet that was accidentally captured by Saturn which then slowly disintegrated? The fact that there is an abundance of water ice in the rings might favour the comet theory. Frankly, I do not know the answer. I doubt if any one else knows for sure. It might be worth pointing out that the thinness of the rings is due to the combined effects of the mutual gravitation of the particles of the rings and centrifugal force.

52. We know that the energy of the Sun arises due to the fusion of hydrogen atoms to form helium, which requires very high temperatures. When fusion first began on the Sun, what was the source of the heat?

You are right in saying that the energy of the Sun is produced through fusion. Fusion can occur only if the colliding nuclei have enough energy to overcome the electrical repulsion between like charges. This energy can be provided through thermal energy of nuclei at high temperature. Your curiosity is about the mechanism through which this high temperature is obtained in the first instance. The argument goes as follows —

Stars are formed through condensation of large clouds of gas and dust. This condensation is due to mutual gravitational attraction. What you require is a small non-homogeneous region that has more than the average density. This results in a greater

attraction to that region; that which is slightly bigger keeps on getting bigger still, very much like how the rich keep getting richer. There is a deep consequence of this phenomenon. In the falling together of matter, gravitational energy gets converted to kinetic energy of particles. These particles collide with other particles that are also falling towards each other. Motions get chaotic, and the agitation of the particles results in the generation of heat and therefore, the temperature rises. If the mass that accretes is large enough, like that of our Sun or other stars, the release of energy can raise the internal temperature to millions of degrees. The higher the accreting mass, the greater the release of gravitational energy and the higher the internal temperature; and higher the internal temperature, greater Is the rate at which the fusion of hydrogen takes place, and therefore, hotter the star. There is a paradoxical consequence of this phenomenon; larger stars consume their fuel at a profligate rate, such that they might live only for a few million years. Our Sun however, which is a medium size star, will survive for at least another five billion years. The big ones do not last long. They die earlier than the smaller ones.

But let me step back a little to illuminate this discussion further. The question of stability of the stellar furnace has to be understood. How does our Sun continue shining with the same intensity, when such dynamic forces are at work? There is no computer control, nor any operator. The reason is simple and elegant. The start of fusion reactions in a collapsing cloud produces energy and increases the internal pressure. When this pressure equals the gravitational pressure of contraction, the star becomes stable. Any decrease in the rate of energy production would decrease the internal temperature and hence the pressure. This would lead to a contraction of the star and hence lead to an increase in temperature and pressure to restore stability. Similarly, were there an increase in temperature, the internal pressure would increase, leading to an expansion of the star and hence internal cooling.

Jupiter is sometimes referred to as a star that did not quite make it, because it was not big enough. Still, it produces more energy than it receives from the Sun! This energy comes, perhaps, from continuous descent of helium under the force of gravity inside the core of Jupiter. Gravity is a very weak force as compared to the electrical and nuclear forces. Nuclear force can act only at short range, characterised by the size of nuclei. While the range of gravitational force is similar to that of electrical force, its influence is dominant because it has the same sign for all forms of matter and energy; it is attractive irrespective of charge or other properties.

53. Matter can be converted into energy during processes like nuclear fusion. Can energy be converted into matter?

Equivalence of mass and energy has been shown in a large number of experiments and natural phenomena. It was first seen in cosmic ray studies when positively charged electrons (positrons) were discovered. A host of elementary particles are produced when cosmic rays interact; nowadays, these phenomena can be better studied in a much more controlled manner in accelerator experiments. For energy-to-matter conversion to occur, all that needs to be assured is that the discrete and dynamical conservation laws are not violated. A high-energy photon cannot be converted into an electron-positron pair travelling freely in vacuum. Such conversion only occurs next to another particle or nucleus that can help to conserve overall energy momentum. This two-way conversion is

an established fact. I might draw your attention to the fact that, in evolutionary cosmology, the Universe itself began as pure energy and all the mass you see was the result of subsequent conversion. Albert Einstein's $E = Mc^2$ stands fully vindicated.

54. How is body temperature regulated in cold-blooded organisms?

The simplest statement in this regard would be that the cold-blooded organisms do not work very hard to control their body temperature within a narrow range. They move to the place that suits their needs. When they want to get warm, they lie in the sun. Otherwise, their metabolic rates function at the tempo the environment and their system allows. It does seem a bit difficult to grasp, but we can appreciate that this is not so hard to achieve. After all, we live on a planet where the temperature can range between zero degrees and fifty degrees Celsius, so there exists plenty of opportunity to find a suitable habitat.

55. How do computers keep track of date and time even when they are switched off?

Computers have electronic clocks very much like the modern watches we wear on our wrist. They have small batteries that continue to run the clock when the power is off. Ordinary button batteries we use in our watches would do, but small rechargeable batteries are also possible. Even for computers, function needs energy.

56. How does electric shock help to treat some mental disorders?

I really do not know the exact answer. I suspect though that the idea originates from the realisation that a lot of functioning of the human body depends on electrochemical signalling mental dysfunction has to do a malfunctioning of this signalling in the brain. Originally, the postulate would have therefore been that electrical shocks might open up some blocked circuits or help to create new pathways. I believe that shock treatment has not gone much beyond empirical intervention, but I could be wrong. We are beginning to understand a fair amount about electrical activity of different parts of the central nervous system and in specific areas of the cortex. I would not be surprised if in the near future, there is significant development in this area.

57. After eating something very sweet, why is the capacity to taste lesser sweetness in other food or drink temporarily lost?

I will hazard an answer even though I am not so certain about its accuracy. Taste buds are receptors that recognise the molecules that give us a sensation of sweetness. After ingesting edibles that are very sweet, these receptors are saturated with molecules. There are few "seats" that are vacant. Therefore, when we subsequently ingest things that are less sweet, our brains receive only weak signals. Therefore, things taste less sweet than they would otherwise.

58. If we expose an object to heat, it expands. Does the Earth also expand, since it is continuously exposed to the Sun's heat?

The Earth heats up during the day and cools during the night. Because of our oceans and the atmosphere, the day and night temperatures do not touch the extremes they would if ours were a dead planet, say like Mars or Mercury. Yet, there is no question that rocks on the surface (as also our buildings and bridges) go through a cycle of expansion and contraction every day. This process does produce some weathering and crumbling. But the temperature of the entire Earth does not change that much. If you were to go a few meters below the ground, you would find that, compared to the surface, you are not as hot during a summer day, or as cold during a winter night. Our Earth as a whole does not inflate or deflate significantly because of the existence of natural mechanisms of insulation. I must, however, qualify this statement. Consider the oceans; the temperature of the sea does change with seasons, but since the winter and summer hemispheres are "connected" by the oceans, the average water temperature is nearly constant. Should there be a dramatic climatic change (for example, due to global warming) which causes an increase in the average temperature of the sea by 5° C, the volume of the sea would increase due to the thermal expansion of water. If we assume that the spread of the oceans will remain about the same and also that the average depth of the ocean is 3 kilometres, increase in the height of the water would be about 3 meters! That could have disastrous consequences for coastal areas and small islands.

59. Has the discovery of quarks challenged the theory of quantisation of charge?

"Naked" quarks have not yet been demonstrated to exist as separate entities. No one has seen or captured the particle carrying one-third the charge of an electron. On the other hand, many properties of matter - as also the way particles behave when they interact with each other - are better understood if quark-like particles are postulated to form their constituents. One could almost say that quarks are powerful theoretical constructs that have proved to be extremely useful in understanding the real Universe. It is possible that free quarks make their appearance at energies not yet achieved by accelerators. Quantisation of charge will not be abolished even then; quarks are still characterised by discrete charge values, even though fractional.

60. It has been said that prolonged cell phone use can increase the risk of cancer. If this is true, does the use of a "hands-free" attachment reduce this risk?

Mobile (or cellular) telephones use a rather intense signal, that of microwave radiation. Some concern has been expressed that this radiation, given the proximity of its source, might affect the brain. The opposing view is that the effects of such radiation are minor (for instance, just a gentle warming, as in a microwave oven set on low), and can be discounted. I do not think there is any agreement on this matter, in spite of the several studies that have been conducted. However, one cannot rule out the possibility of other effects, and one should keep in mind that there are vested interests involved; after all, mobile telecommunication is big business. It pays to be careful, but one should not become paranoid. Of course, any possible deleterious effect can be reduced significantly by increasing the distance of the transmitter from the head, say by using something like a

hands-free system. However, an enthusiastic transition in that direction might turn the mobile into a speakerphone!

61. Why do tides occur only at the seashore, but not in deep ocean?

If you were sitting on a satellite far out in space and had an instrument to measure the distance to the sea level below, you could quite easily discern the effect of the Moon on tidal phenomenon; high tides would be observed relative to the Moon's position. You would also see more water at the diametrically opposite end of the Earth, while the level of the sea at right angles to the Earth-Moon line would be lower -we shall neglect the Sun's influence for our discussion. The tidal force does not depend on how far you are from the coast. The reason why you are more aware of the rise and fall of water when you are near the coast is because you have something to compare these changes with; your point of reference is the unchanging level of the coast. In the midst of the ocean, far from the shore, all the water in the neighbourhood rises up in the tidal swell and then recedes, and one is unaware of this gradual up and down motion twice a day.

62. If the Universe is expanding, what is it expanding into?

One cannot define space without the Universe. In a sense, the Universe expands into space that it itself creates! I know this appears confusing, but I do not know how else to answer your rather perceptive question. Part of the problem stems from the fact that our minds cannot get away from conceiving the Universe except as a three dimensional non-relativistic space.

63. Why is it cooler in the hills than in the plains?

The Earth is surrounded by an envelope of air we call the atmosphere. The atmosphere has pressure. This pressure can be considered as weight of the air column. At sea level, this is a little over a kilogram per centimetre square. As we go higher, there is less and less air above us. This means that the pressure of the air must decrease with increasing altitude. This would imply that if I take one litre of air from sea level to an altitude where the pressure is reduced to one half of that at sea level, the volume occupied by that air will become twice i.e. 2 litres. Air expands when its pressure is reduced. But we also know that when air expands, it cools. We experience this in everyday life as well; when you press the valve pin of an inflated car tyre, the escaping air is cold. Also, you must have noticed that when you are pumping air into your bicycle tube, the hand pump gets warmer. This is because the random energy of the air molecules is reduced when they move further apart from each other; this happens because the molecules have to work against the attractive force between the gas molecules. Thus, the natural stable state of the atmosphere is one in which the temperature decreases as the pressure decreases - in other words as the altitude increases. That is why it is cold up in the mountains. You must also remember that air is heated primarily through contact with the ground and infrared radiation coming up from the Earth's surface; little sunlight is absorbed by the atmosphere on its way down to Earth.

64. What happens if protons and anti-protons are allowed to interact?

Useful imagery in this regard was provided by Paul Dirac when he propounded the theory of the electron, way back in 1930. It was suggested that when an electron is created, a hole is left in the vacuum. This hole would behave like an anti-particle of electron; it would have a positive charge. Thus was born the concept of particles and anti-particles. Incidentally, the positive electrons, later called positrons, were later discovered, validating Dirac's theory.

Thus, given enough energy, a proton and anti-proton pair can also be created from vacuum. And the reverse is true as well; when a proton and an anti-proton meet, their rest mass energy is released in the form of particles of lower energy, including electromagnetic energy. Thus, a proton can annihilate an anti-proton, producing a burst of energy. The energy released in a quiet handshake of the two would be determined by Einstein's equation $E = Mc^2$, where M is twice the mass of a proton and c the velocity of light. All these concepts and theories have been experimentally validated in an exhaustive manner.

65. Why do fingerprints differ between individuals?

Why should it be surprising that fingerprints of different persons are distinguishable? The reverse would have been more surprising by far. After all, it's rare to find two people looking exactly alike. Just think how we are put together, molecule by molecule. It is truly amazing that we come out so similar, though not exactly the same. We should also remember that there are always slight differences between the DNA of different persons, except maybe of identical twins. This arises from inheritance. Mutations over a long period of time and mixing of genes does bring about some differences, some marks of identity.

66. What is the relationship between astronomy and astrology? If such a relationship exists, is an astrologer an astronomer?

This would need a slightly long answer. But I shall give you the short version. Even though the origins of astrology and astronomy may have been the same, today's astrology has little to do with astronomy. In fact, astrology is not a science at all, I believe it preys on the human need for sustenance and support, it seeks to absolve humans of the consequences of their actions and it resigns them to their "fate". Astronomy, on the other hand, is today a vibrant science, which rejects the supernatural (such as the influence of planets on our lives), and strictly abides by all known laws of nature.

67. Why is the sky blue, despite the fact that light comprises seven colours?

What we normally call "sky" is nothing but the light that comes to our eyes after it Is scattered by air molecules in the atmosphere. If there were no scattering of light by the air, we would see only stars studded on a black firmament. This is precisely what the "sky" looks like to astronauts in space. Our sky is blue because the degree of light scattering by air increases rapidly as the wavelength of the light decreases. Blue represents the short wavelength end of the visible light spectrum. I might also draw your

attention to another commonly observed fact, namely that the setting and rising Sun appears a reddish orange. The reason for this is the same that makes for a blue sky. The shorter wavelengths of light are preferentially scattered away while passing through the thick layer of the atmosphere. This leads to a predominance of longer wavelengths of light, namely the orange and red, reaching our eyes from the Sun's disc.

68. Despite the tremendous repulsion between positive charges, how do multi-proton nuclei exist?

We know that Helium 2 (He2) does not exist. In other words, a nucleus with only two protons cannot exist. But He3 does exist; the nucleus of He3 has a neutron, in addition to the two protons. The reason He3 exists is that there is strong attractive short-range nuclear force between all nucleons - protons and neutrons - alike. The character of this short-range force, called the Strong Force, is different from that of the electrical force. Thus, inside the nucleus we have two opposing forces - repulsion between positively charged protons and attraction between protons and neutrons. With increasing atomic number, the number of neutrons is significantly greater than the number of protons, to compensate for repulsive force. Thus, the abundant form of Uranium has a total of 146 neutrons and only 92 protons.

69. When light travels from one medium to another, its speed changes. Do its wavelength and frequency change as well?

Light, like other forms of electromagnetic radiation, is an oscillating electromagnetic disturbance that propagates in a direction normal to the direction of oscillation. Wavelength is defined as the distance this disturbance travels during one oscillation. Therefore, it is calculated as the velocity of propagation divided by the frequency of oscillation. In traversing from one medium to another, it is the velocity of propagation that changes. This would affect the distance the disturbance travels in one cycle of oscillation, which is the wavelength. Using these criteria, it would seem that frequency is the basic property, while wavelength is a derivative quantity. Frequency is determined by the characteristics of the source.

70. Is Time also quantised, as various other physical quantities like electric charge and angular momentum of an electron are?

I do not think quantisation of Time is a very useful concept. We have the discrete quantum numbers like charge, baryon number etc. They help define non-dynamical conservation laws. We also have the dynamical quantities like momentum, angular momentum etc. One might say that Time is subsumed within dynamics - for example, velocity and momentum do involve Time. How would you go about separating quantisation of Time and momentum? 'h' is called the quantum of action. Its dimensions are energy multiplied by Time (erg x sec). In that sense, Time already enters as an entity in quantum thinking.

71. Even though water is colourless, why does seawater look blue?

The simplest answer is that water is not completely colourless, or transparent. It does scatter light and this scattering is wavelength-dependent. Algae on the surface and other forms of life also influence ocean colour.

72. At the atomic level, what are the factors that determine the transparency and colour of a medium?

Glass is transparent for visible light. It is not so transparent for infrared, or other frequencies like X-rays, for example. Our atmosphere is conveniently transparent in the visible region of the spectrum, where the Sun gives out most of its radiation, and where our eyes are most sensitive. But the very same atmosphere is opaque in most frequencies of infrared, ultra violet, X-rays and gamma-rays. Therefore, as you suspect, transparency, or otherwise, depends on the detailed structure of the material. Atomic and molecular structures are of central importance in determining the scattering and absorption of radiation. Atoms and molecules have specific energy levels. They determine which part of the spectrum would be absorbed and which would pass through unhindered. Indeed, in most of experimental science (including atomic physics, molecular physics, a lot of chemistry and biology, astronomy and even nuclear physics), we use different types of radiation to probe structure. Experiments are interpreted with the help of known theory; on the basis of new results, however, newer theories often emerge.

The question you have asked is basic to much of modern day science activity. An example from the current concerns about depletion of the ozone layer might illuminate the discussion. Ultraviolet light would reach the Earth if there were no ozone. This is because the atmosphere does not have other molecules in quantities high enough to absorb this radiation. Ozone molecules that are formed in the upper atmosphere are structures of three oxygen atoms which demonstrate relatively loose interaction with each other. The energy level of ozone molecules is such that they are capable of absorbing the ultraviolet, leading to their breakdown into oxygen molecules and oxygen atoms. Ozone molecules are destroyed, but in the act of dying, they manage to save us from harmful effects of ultraviolet radiation. Of course, we need continuous replenishment of ozone to compensate for the warriors that perish in trying to save us!

73. When you boil milk, you have to be very careful to ensure that it does not boil over and spill on the burner. There is no such problem when you boil water. Why?

Milk is not a simple liquid like water; it is a congregation of several molecular species. It has tiny globules of fat in a colloidal form. It also contains casein and several other things. They are not dissolved in water, the main constituent of milk, but are suspended in it. When milk is heated, the convection and agitation separates the cream along with some other constituents which, being lighter, slowly float to the top. There they form a sticky, creamy layer covering the entire surface. The edges of this layer in contact with the hot sides of the vessel get anchored there; slowly forming a membrane of ‘malai’ begins to cover the entire surface of the liquid below. When the milk boils, the steam pressure below the membrane increases suddenly. The membrane is punctured and the milk and ‘malai’ spill out in a foamy mess.

You must have noticed that if you want to make milk cake ('khowa'), you have to continuously stir the milk while it is on the boil. This is to stop the sticky creamy layer from forming a membrane. You know, of course, that you also have to scrape the bottom of the vessel to ensure that the stuff that sticks at the bottom of the pot is continuously scraped away and is prevented from burning into a dark brown mess.

This is not a textbook explanation. You are welcome to add to this, criticise it and give other comments. Consult a 'halwai if you like or, better still, your grandmother. Incidentally, I have been told that making of good 'malai' is quite an art. Learn from a master craftsman when you next visit Jaipur.

74. How do solar flares affect us and when is the next solar flare heading for Earth?

Solar flares are explosions on the solar surface in which large amounts of ionised coronal material is thrown out. Much of this material falls back on the solar surface, but quite a lot is expelled outward at great speed. This solar plasma contains nuclei of various elements present on the solar surface, along with electrons; it travels out in space, dragging with it the magnetic fields of the solar surface. During such flares, the ever-present wind of plasma is greatly enhanced, both in the number of particles and their speed.

When these particles arrive near the Earth, they deform its magnetic field. The field is compressed in the sunward direction and stretched out in the direction away from the Sun. This produces magnetic storms and sometimes a strong disturbance in power lines. Radio communication is also disrupted. Satellites and astronauts in space can be exposed to high doses of harmful radiation. While the low energy plasma cannot enter the atmosphere of the Earth at low magnetic latitudes, it pours in along the magnetic lines of force near the poles. The resulting ionisation produces the spectacular "Aurora Borealis" or "Northern Lights".

The point to remember is that the Sun does not send us only its light, heat and other electromagnetic rays. It also sends us samples of its surface material. To some extent, this happens all the time in the form of a "wind"; this wind becomes more intense after large solar flares.

Exact prediction of solar flares may not be currently possible, but scientists are getting better at it all the time. Large solar flares appear to coincide with the 11-year sunspot cycle. The Sun is supposed to be in an active phase at that time and this is visually reflected in an increase in the number of sunspots. Sunspots are locations of intense magnetic field on the solar surface. By studying the varying structure and concentration of these spots and other features, reasonably good predictions of impending solar flares are now beginning to be made. After a flare is actually seen, the solar particles take some time to reach the neighbourhood of the Earth, since the typical speeds of the ejected particles are only of the order of a few hundred kilometres a second. If light, with a speed of 300,000 kilometres per second, takes about 8 minutes to travel from the Sun to the Earth, the solar wind would be travelling for about 8000 minutes before it hits the Earth. The trip might take even longer, because the path of the solar particles is curved by the magnetic field that exists between the Earth and the Sun.

75. You are driving a car and the brakes fail. You see two walls ahead of you, one fresh and 'kucha' and the other solid, cemented and 'pucca'. Which one would you chose to hit and why?

The 'kucha' one, for it will in all probability, be knocked down and won't bring the car to a halt quickly, thus minimising the shock. The point to remember is that the rate of deceleration should be as small as possible. Therefore, it is essential for the obstruction to "give" a little. In this connection, let me recount a personal experience. Many years ago, I used to fly scientific equipment to very high altitudes using stratospheric balloons. We used a parachute to slow the descent of the instrument, but the impact while landing on Earth was still quite strong. After much thought and experimentation, we found that long stacks of egg crates cemented together and tied below the instrument made the best shock absorbers. The heavier the payload and higher the descent speed, the broader the stacks of egg crates we employed (without the eggs, of course!!) to ensure a slow deceleration to rest. In other words, the descent velocity is reduced to zero over a longer distance. This has now become standard practice for balloon flights from Hyderabad.

76. Why does a bird flying high up in the sky not cast its shadow on the ground?

Let us assume that the bird is a round object, 30 centimetres in diameter. If it is flying at an altitude of 300 meters, it would subtend an angle of 30 divided by 30,000 or one thousandth of a radian, which is about one/ seventeenth of a degree. The angular diameter of the Sun is about half a degree, which is about eight times bigger. Therefore, the bird will fall far short of covering the Sun, a condition for it to be able to cast a sharp shadow. The basic reason is that birds are small and the Sun is not a point source of light. Actually, most birds are better described by a size 10 cm. by 10 cm; therefore, they would cast fairly good shadows only if they are no higher than 10 meters. Of course, there would be some reduction of light intensity as the bird transits across the solar disc - but it is not recognisable as a shadow.

77. If I press the upper lid of one of my eyes I see two images. Why?

The two eyes send independent image signals to the brain, which has the software to combine them to give the sensation of a single 3D image. When we press on one eyelid, we are essentially tilting its lens, and therefore moving the image on the retina. The brain is taken unawares and the two visualised images are the result of improper superposition. However, it soon realises that the sensation it is giving is not consistent with the real world. Therefore, it gets down to making the proper registration and corrections and you begin to 'see' only one image again. The software correction capability of the brain is reminiscent of methods employed to correct aberrations in optical telescopes.

78. When a ball falls to Earth under the influence of gravity, potential energy converts into kinetic energy. Which energy contributes to its rebound off the ground?

When the ball hits a hard surface, the kinetic energy gets converted back into potential energy, which resides in a spring-like compression of the ball itself and the spot on the ground it hits. Let us also look at the kinematics. If the collision Is completely elastic, meaning no energy is lost due to the generation of heat or the disintegration of the colliding objects, the energy and momentum have to be shared between the ground and the ball. Since the ground is so much more massive, it can easily absorb twice the original momentum of the ball without extracting significant energy. So the ball bounces back.

79. How do dogs hear sounds at frequencies higher than those perceptible to humans?

Different living things have different capabilities (indeed, that is why they are different!). Dogs can hear ultra high frequency sounds that we cannot.

They can also smell things that we cannot. That is the reason dogs are often used to track down prey and people. Many birds, and even bees, can detect polarisation of skylight (which helps them navigate even when the Sun is not directly visible when the sky is overcast). I am ignorant of the evolutionary cause that gave dogs sensitivity for higher frequencies of sound, although there must be one. We should never think that we are the most capable animals on this Earth. Perhaps that is one of the reasons we have been able to develop different technologies to assist us. It could be that having a hearing apparatus sensitive to high frequencies may not have conferred any special advantage for our survival, given all the other attributes we possess.

80. Why and how does the Earth rotate?

Like all heavenly bodies, the Earth also has a history. It did not come to exist because someone took out a fully formed ball of rock, sand and water and placed it carefully in space. The Earth came into being rather slowly, through the same process that finally created our solar system. The most sensible theory in this regard is that this process was one of gravitational contraction of a large cloud of dust and gas. Such clouds are seen in different parts of the galaxy and are believed to be the sites where new stars and their planets might ultimately emerge. Wandering clouds pass by other clouds and, sometimes, massive condensed objects. The gravitational force between the objects makes them rotate slowly. The probability of a cloud having zero rotation is also zero. It is believed that stars form through contraction of these clouds, due to the force of gravitation. In this process, the clouds become discs that are thin in the direction of the axis of rotation and look like saucers. The central portion of this disc condenses to become the star, while the matter in the periphery could accrete to form planets around the star. The whole process is such that every thing comes out rotating and/or revolving. This is primarily due to the conservation of the angular momentum of the slowly rotating, contracting large cloud. This is the reason that the Earth, the Sun, the Moon and all the planets rotate - rotation is acquired in the process of their formation. Afterwards, you do not need any force to keep them going.

81. How do animals know who their parents are after they are born?

I am not an expert in this area, but it must have something to do with the touch and the care given to the newborn by the mother. I doubt if the baby also knows who its father is. I am sure the sense of smell is intimately involved. I vividly remember an episode when I was a child of seven years living in Quetta. We had a cow on whose milk we depended for nourishment. The cow was pregnant and we were eagerly awaiting the birth of its calf. Unfortunately, the calf died during birth. *The* cow was sad and refused to be milked. After a couple of days, the milkman brought back the skin of its calf wrapped around a bundle of straw and placed it before the cow at the time of milking. The cow eagerly started licking the bundle and the milking proceeded smoothly. From then on, that bundle was always required before milking. The smell of the skin was immediately recognised as that of its offspring. I am sure the sense of smell also helps the baby recognise the mother.

Incidentally, cheating the poor cow like that was a sad thing to do, and her grief stayed with me for a long time. We are now in an industrial age, where vacuum milking machines just suck the milk out. Sad and cruel.

82. If one stands at the North Pole with a magnetic compass, which direction would point north?

The first thing you have to remember is that the geographic North Pole of the Earth is not exactly coincident with the magnetic pole. The compass will point in the direction of the magnetic pole. If your compass needle can also rotate in a vertical plane, you would also see a large angle of dip. The magnetic lines of force at the magnetic north are perpendicular to the surface of the Earth. In the equatorial regions of the Earth, these lines are nearly horizontal.

83. When someone meets with an accident involving a head injury, why is there sometimes only a loss of the faculty of memory and not of other abilities such as the ability to walk or talk?

This is an area about which I know even less than I do about many others. Indeed my answers to most of your questions are not based on a truly expert knowledge in any particular area. In regard to this question, it seems to me that the brain is an excellent manager who believes in giving functional autonomy. When you are walking down the stairs, swimming, eating, playing cricket, even breathing, and the brain does not bother to interfere in functions that have already been delegated. Yes, it can override many decisions, but this is done rarely. That must be why a head injury does not shut down the shop. The manager might be out on a holiday but-the factory works. Coming now to the specific question of memory loss after a trauma.

In most instances, all memory is not lost. A person might forget who he or she is, may not even recognise a known face, but still might be able to speak, write and do arithmetic. I think the brain stores memories at different locations. Short-term memory is perhaps the most volatile and more susceptible to erasure. An instance in which an accident victim forgot his mother tongue but not a foreign language has intrigued me. Perhaps even the manner of learning one's mother tongue is radically different from that of learning a foreign language, not only its location in the brain. Language arid concept formation

must be closely linked. Perhaps the mother tongue connects us to a more nascent, different, conceptual world than does a foreign language.

On a related note, I have serious concerns about English being the first school language for children for whom it is not the language of their home and environment.

84. What happens to a magnetic substance when it is placed in water?

Nothing. The substance just gets wet. Actually, that might not be true in all cases. Supposing the magnetic substance is a conglomeration of magnetised particles bound together by dried up soil. After getting wet, the magnetic particles might become free and align themselves in the direction of the existing terrestrial magnetic field. Slow settling of such particles along with soil would form layers, which then become rocks, retaining the direction of magnetisation, and hence aligned with the Earth's magnetic field at the time when the rock was formed. Such studies have led to conclusions about continental drift, as also the fact that the Earth's magnetic field has reversed poles several times in the geologic past.

85. When we eat while sitting or standing, the food moves down into the gut due to the force of gravity. How can people then sometimes eat while doing 'sheeshasana'?

Food does not descend into the gut due to gravity. When we eat, the food pipe compresses and presses the food down into the stomach. This is much like the way a snake devours a field rat (incidentally, it does it while lying flat on the ground). Also, astronauts eat under conditions of weightlessness. Here, I am reminded of an anecdote which Richard Feynman, the distinguished physicist, narrates about his college days. Some of the students in the dorm maintained that one could pee only because of the force of gravity. Feynman contested this and proved his point by demonstrating that he could pee while standing on his head!

86. What makes people believe in superstitions, in the absence of any scientific proof or logic? Do we know for certain if God exists? Magic appears to defy all logic. Is it real?

This is not just one question, but at least five. Any one of these can take several pages to answer. But I will be brief. Some of my replies would be biased and personal.

In my view, superstitions arose at a time when there were no better answers available to people's curiosities and concerns. People sought co-relations between happenings and events, particularly those that affected them. These acquired the status of rational explanations. We should have an understanding attitude towards superstitions and view them as components of the cultural history of humanity. Many rituals are also manifestations of the same social and cultural heritage; they might appear senseless at times but they carry with them the stories, myths and beliefs of an earlier time. It is true that there are people in the world who still give these superstitions the same status as rational explanations. That is sad. There are many things we understand at an intellectual level as grown-ups; frequently, however, the "brainwashing" to which we are subjected

from childhood, influences and modifies our actions. Knowingly or otherwise, we foment and propagate religious, racial, linguistic, ethnic and national conflicts, knowing all the while that our children stand to inherit a common future.

You have asked me if there is such a thing as magic. Yes, there are magicians who are very gifted and clever individuals, who know a lot of tricks, are masters of sleight-of-hand manipulation and, in addition, are cunning psychologists. I do not believe that any magician, even a so-called holy man, can circumvent the laws of physics.

You have asked me about the truth of existence of God. Any reply I give can be misunderstood. This is a personal matter, a matter of faith. I do not think that one can scientifically prove the existence, or indeed the non-existence, of God. As far as I am concerned, any God I choose or create for myself would lose my reverence if He started to interfere with the laws He himself had so beautifully designed.

87. Why is it that seawater continues to be salty when thousands of rivers keep discharging fresh water into the sea?

The sea is salty precisely because it is only a sink for most rivers and not the source of any. Rivers keep pouring into the sea but its level does not rise - at least on a time scale of decades. The oceans lose about the same amount of water through evaporation as they get through the rivers. What keeps accumulating in the oceans is the salt and minerals dissolved in the 'fresh' water of the rivers. The water goes back onto land in the form of rain and snow to feed the rivers that bring another load of the salt and minerals from the land surface. The process continues and the salinity of the oceans keeps increasing. It will reduce significantly if large ice masses on Antarctica were to slip into the sea, bringing back a large supply of truly fresh water into the sea that was taken from it over millions of years. This will happen if catastrophic global warming were to take place, raising sea levels by tens of meters.

88. How do species evolve camouflage?

Species evolve through greater adaptability. If some members of the species happen to develop a mutation which gives them the capability of blending with the environment, they will escape predators with greater ease than those who have not. Ultimately, they will become the dominant population. Evolution does not happen through trying; it is the result of random mutations, and propagation of the species and/or individuals that can best adapt to a changing environment.

89. Why is it difficult to walk on sand or ice and not on a smooth or solid floor?

Anything that wants to move forward must push something backward. If there is nothing to push against, we cannot move. When we bicycle, walk, ride a motorcar, bus or a train, we are pushing the whole Earth backwards! When we fly a propeller plane, we do so by pushing large masses of air backwards. In a jet plane, the gases produced by combustion of the fuel are thrown backward at great speed, providing the forward thrust. Similarly, rockets move up by pushing the gases produced by the burning of the rocket fuel downward. If the surface is rough, it is easy to push the Earth back when you walk.

If it is slippery, any effort to push backwards leads to slipping, not pushing, and no forward motion results. On sand, there is some movement because sand does hold on to the Earth through friction; pushing of sand itself could be quite efficient if it could be thrown back at high speed, but we cannot move our feet fast enough to do that. It would also help if the surface area of our feet were much greater, enabling us to push against large masses of sand. This is a feature on which a camel easily scores over us. The basic requirement of conservation of momentum must be fulfilled. Have you ever considered that when you walk or run, you disturb the whole Earth, albeit in a miniscule manner? We are not insignificant!!

90. If we burn a piece of cloth, it catches fire immediately. But if we dip it in oil, it burns slowly until the oil is over. Why?

The temperature at which cloth catches fire is higher than the temperature at which oil catches fire. Oil is more combustible. When we light an oil-soaked cloth, or the wick of a lamp, the heated oil vaporises and it is this vapour (mixed with air) that burns. The temperature at the base of the flame, close to the wick, is rather low, while near the top it can be quite high. This is because of the convection of heated vapour and ample availability of air which rushes in from all sides. The oil on the cloth actually keeps it cooler, much below the level at which cotton would burn, so while the wick of the lamp turns brown slowly, the oil keeps rising, getting converted to vapour and burning away from the cloth. A flame is therefore a rather beautiful interplay of various physical forces. Imagine what would happen if there were no gravity and, therefore, no convection; candles and hurricane lamps would be in real trouble!

91. Why are there lines on our palms? What do these lines have to do with biological evolution? Do they determine our fate?

Primarily, the lines seem to mark the interfaces between various manoeuvrable components of the remarkably versatile internal structure of the hand. Wherever we require bending or twisting, it is necessary to ensure that the skin folds properly. The ability to close the hand into a fist naturally demands that we have horizontal folds on our palm.

This may be the reason for the so-called ‘head’ and ‘heart’ lines. The thumb does a lot of bending, especially in concert with other fingers for holding, Grafting, writing, eating drawing, picking up things, shooting an arrow and much else (remember the story of ‘Eklavya’?). This requires that we have the so-called ‘life line’. The hand is capable of a great many other manoeuvres - think of a dancer’s “mudras’, the finger movements of a spin bowler, or many other operations in which we use the hand and fingers selectively and at will, without having to first arrange the creases on the covering skin of the hand. Let us not forget the complex set of lines marking the positions where we can bend each finger or the folds around the knuckles at the back of our hands. The lines on the hand are a requirement of an amazing engineering design. Clearly, there is much more than what I have indicated here; it is all a result of millions of years of evolution.

It is, of course, amusing to look for correlations between the detailed imprints on our palms and our future, but it should remain just an amusement. For me, the importance we

give to the date and the place of our birth is equally amusing. A major industry has developed around these aspects, largely exploiting the in-built insecurities of us humans. Correlations can always be manufactured, if you do bad or dishonest statistics. I do not have any faith in these things, though I do grant that palm reading is a rather enjoyable and harmless pastime.

92. What does it take to be a Nobel Prize winner?

Nobel Prize winners are not demigods, but usually they are rather creative people. They are also those who have dared to think thoughts that were not very conventional or fashionable. And they are astonishingly hard working. Work for most of them is not arduous or unpleasant. It is something they just cannot help doing. They often are prisoners of great passion. Though some lobbying might help, usually it is superfluous, even counter-productive. Your work must be exposed to the scrutiny of your peers; you cannot get a Nobel Prize for doing something great and not telling anyone about it.

93. Have humans really landed on the Moon? I understand that reflection of light does not occur on the Moon's surface. However, in many published photographs, reflections are clearly visible in the visors of astronauts. Could Moon landing be a fraudulent claim?

You are a very suspicious guy. I have heard a number of people say that the Americans created a show to fool the world. Many of the same people believe that India had airplanes and remote sensing capability in days of Ramayana and Mahabharata! I do not understand what you mean by saying that on the Moon there can be no reflection. If Moon did not reflect, or scatter light, you would not see it. If you meant to say that there should be no shadows on the Moon, you would be wrong again. The Moon is just a piece of rock, much like the Earth (though quite a bit smaller), and the laws of nature apply there as they do everywhere else in the Universe.

I may mention that I have personally met the guys who have been to the Moon, as also others whose instruments, placed on the Moon by these astronauts, have yielded valuable scientific results. I also have friends who have done valuable work on the Moon rocks brought back by the astronauts. Scepticism is good, but groundless suspicion is corrosive, besides being petty.

94. Why do large lakes not produce waves as seen in the ocean?

Waves arise from the action of wind on the surface of water. For big waves to form, a steady wind needs to act over a significant expanse of water. So the only answer that I can give you is that your large lake is not large enough.

95. How did the Moon escape the process of "differentiation" and become cold and hostile while the Earth became a warm and hospitable planet, when both have been bombarded by meteors?

The history of the Moon and the Earth is best studied from the many books and papers written about this subject. I would just refer to one or two physical aspects. Large heavenly bodies get hot inside because of gravitational contraction - they keep falling in on themselves. Sometimes, they also have trapped energy sources; for example, a lot of heat inside the Earth is generated by the decay of radioactive elements, particularly an isotope of the element Potassium with a mass number of 40. In the case of Jupiter, it is believed that its immensely high temperature inside and net export of radiant energy is due to slow gravitational falling in of helium from its upper levels. Large planetary objects also cool slower than small ones because their surface-to-volume ratio is lower. That is the reason why elephants enjoy bathing; it is hard for them to dissipate energy produced in the metabolic process. That is also the reason why individuals who are overweight perspire more - evaporative cooling helps reduce temperature. On the other hand, the reason small birds keep feeding continuously is that, with their large surface-to-volume ratios, they radiate (and therefore lose) a lot of the energy that is produced by food metabolism. If they allow themselves to get too cold, their metabolism will slow down, which in turn would result in a further decrease in temperature. Death would be the inevitable consequence.

96. Why does an air conditioner "leak" water?

An air conditioner sucks in the outside air and passes it over fin-like projections, which have been cooled by the compressor. It cools the inside of a room while heating the outside. Now, back to your specific question. The outside air is not only hot but often it is also quite humid. When passed over the cold fins, the temperature of air drops below the dew point and excess moisture condenses out. The external surface of a glass of cold ice water becomes wet for precisely the same reason. The glass is impermeable to water. The water comes from the cooled air. The early morning dew on grass is a result of the same process. At night, the Earth cools more than the atmosphere. Moisture-laden air touching the cold ground cannot carry its load any more and deposits it on grass, in the form of glistening droplets. No, the air conditioner does not "leak" in the conventional sense; it extracts the water from the air it is cooling. This process is particularly spectacular if your air conditioner is efficient and the humidity of the outside air is very high. I have always felt that we should find ways to harvest this distilled water, which is produced by the bucket-full, purely as a by-product.

97. Can we somehow hold Time still or go backwards in Time?

You can, of course, take a film of some event and run it backwards. That way you can see yourself moving up a slide, or see water going back into the tap instead of coming out of it. Pieces of broken glass fly back and join up to give back the whole pane that you shattered with your cricket ball. Such trivial tricks are used in stunt movies and by now every one knows how it is done. However, the laws of physics do not allow your getting younger. The arrow of Time is sometimes defined as the direction in which the entropy, the degree of disorder of an isolated system, only increases. It is also the direction in which the Universe is expanding. Einstein postulated that no physical object could travel faster than the speed of light. That eliminates the possibility that you might overtake the light waves from the moment you received a prize so you could revisit the glory of that

moment! No, Time cannot be reversed in any real sense in the macro world of our experience.

But this is not a total loss. We have the record of all our experiences in our memories. We can recall them any number of times and re-live any chosen moment. As you age, memories acquire different hues and inflections and old incidents and happenings are often enriched and made more special. Of course, such living is not objectively the same as the first time it really happened. But that is an advantage. One of the joys of life is to see our past through different filters depending on the mood of the moment, or the years of later living.

98. Why can't we wear bio-electronic devices that forewarn us about impending disease such as cancer, AIDS etc?

There are sensors available for monitoring some parameters of health. These include blood pressure, blood sugar etc. It is inconvenient to wear these devices regularly but it does not seem impossible that future technology may make them user-friendlier. For example, one can imagine a small shunt in the blood circulation system, which passes through miniature analysing equipment that can ring a bell when some blood parameter is abnormal. But these devices will at best detect those diseases that quickly impact the properties of blood. I do not know whether such systems could provide early warning about all forms of cancer. I am no expert in this area and I cannot rule out the possibility of revolutionary developments in this field. However, I am a bit sceptical about the benefit of such systems, if permanently fitted to every individual. They are likely to produce many false alarms and create a climate of health neurosis. On the other hand, there could be systems in kiosks, if not homes, which could provide quick scans, along with some analysis. In principle, this information could also be transferred to a physician using the Internet for advice and diagnosis.

I am reminded of the stories of how some *Vaids* (traditional healers) and 'hakims' could diagnose disease just by feeling your pulse. I also re-collect the experience of seeing a mechanic tune a car engine by putting his ear to the open bonnet of the idling engine and fiddling with parameters like the fuel mixture, the timing and the idling speed. The engine "talks" to a good mechanic, who has the friendly ears and the mental software to decipher its language. Perhaps we will have such intelligent, miniaturised and user-friendly components some time in the future. As for me, I will still leave them home to avoid a perennial preoccupation with my health that would get in the way of me living my life. Actually, there are many ways in which our bodies tell when something is wrong; that we do not always listen is another matter. It is unlikely that we would change the way we behave if the alarm bells were sounded by computerised miniature implants; we will probably take out the batteries!

99. How can we get an estimate of the mass of the Earth or of other planets? How do we measure their sizes?

One way of estimating the mass of the Earth might be to first find out its average density and then its volume. Multiplying the two should give an estimate of the mass. But

this does not work very well because there would be uncertainties in determining the internal constitution of the Earth.

The best way of measuring the mass of a gravitating body is to see its effect on a test body that is affected by its gravity. Let us assume that we have a satellite of mass m going around the Earth in a circular orbit at a known distance r from the center of the Earth. Let M be the mass of the Earth and G the value of the gravitational constant. Then, for the orbit to be stable, the force of gravity would be equal to the centrifugal force. In other words

$G \times m \times M / r^2 = mv^2/r$, or

$v^2 = G \times M/r$

Note that this would be strictly true only if mass m were negligible compared to the mass of the Earth. If it were not, we would need a slightly more complicated analysis but the principle would remain the same.

If the orbital period is T, then

$T = 2 (pi) r / v$, or

$v = 2 (pi) r /T$

Thus we get,

$M = (27 [pi] / T)^2 \times r/G$

$= (4 [pi]^2 r^3) / (T^2 G)$

Thus, the mass of the Earth can be measured by measuring the distance and period of a satellite of the Earth. In this calculation, the mass of the satellite is irrelevant so long as it is small compared to that of the Earth. One can have other variations of the method. But we always have to appeal to Mr. Newton, and we have to know the distance between the two objects.

The size of a heavenly body, a planet for example, can be determined by measuring the angle it subtends - and its distance. The distance could be measured using radar techniques, but it can also be estimated by using its period of revolution around the Sun and the value of the solar mass. The solar mass is calculated by analysing the orbit of any of its satellites - the planets.

100. How does a 'puri' puff and why is one of the sides thicker than the other?

When you put a rolled puri in hot oil, the top and bottom faces, as also the edges, are quickly cooked well enough to become impervious to the steam generated inside. The puri bloats a little and floats to the surface. Now it is heated mostly from the bottom surface that is in contact with the hot oil. The wet dough soaks up this heat and coagulates but stays stuck with the bottom layer, making it thicker. The occasional submergence of the top surface, done at the instance of the cook, makes it brown and stiff. The steam pressure inside separates the two layers, giving us a delicious looking puri. Notice that the difference in the thickness of the two layers arises from differential heating in the initial stage when the heat capacity of the dough is high.

101. Why are there no tides In the Mediterranean Sea - or in lakes?

At the time of high tide, the water level rises. The density of water does not change, The increase in the volume of water in the region of the high tide has to be made up through a supply from somewhere else. For a closed sea like the Mediterranean, or a lake, there is no inlet that is wide enough to allow large volumes of water to come in. Surely, one cannot have a vacuum under the bulge of high tide. Similarly, a low tide can occur only if water can quickly flow out to the areas of a high tide. That is not possible for a sea like the Mediterranean - or in lakes.

102. When we swallow an aspirin tablet for an aching organ, how does the drug know where it needs to act?

Aches and pains are sensed and experienced through the brain. The signal of trauma in the body is communicated to the brain along with the address of the location from which it originates. That is how T know where it hurts and how much. The T is located in the brain. If the incoming signal is blocked, or the threshold of the sensing element in the brain is raised, I stop feeling the pain. There are some drugs that affect the sensing threshold. Aspirin is one of them. Different types of opiates act in the same way.

The phenomenon and physiology of pain continue to be subjects of intense investigation. It seems that the brain is not just a passive recipient of signals of assault with a finger on the alarm button of pain. It also sends communiqués to the area of the assault, changing the threshold of reception to survey the extent of damage. While autonomous agencies set about the job of repair - suturing the wound and clotting the blood - the brain seems to keep an active overview. If the signals of trauma are much too strong, opiates attenuate them - opiates *that the brain itself is capable of manufacturing!* If particularly acute, trauma can lead to the suspension of all sensation and awareness, resulting in unconsciousness. The more one learns about this function, the more one marvels at the sophistication of the management technology used by the living world. In spite of its much faster speeds, modern information technology does not compare in terms of sophistication, autonomy, reliability and economy - another example that teaches us to be humble.

103. What keeps Earth revolving round the Sun?

Think of a carom board; you must have played on one. A good board is one whose surface is smooth. You can make it smoother by sprinkling some talcum powder, or borax powder, on it. On such a board, a striker moves fast and smooth. The rebound shots work better. Smoothening the surface reduces the friction that normally obstructs the movement. Indeed, you can reduce the friction even further by playing on an air table. This is a smooth table with a large number of tiny holes through which air is blown outwards, causing the striker and the coins to float on a cushion of air. Surface friction is largely eliminated. On such a table, the coins will stay in motion for much longer, hitting the walls repeatedly and bouncing back and forth. Experiments and observation of this type should encourage you to extrapolate to a situation where all friction is eliminated, including the friction with air. If through such extrapolation, you had the insight to frame a law of nature which states that,"a physical object will continue to move with a uniform

velocity unless some force acts on it", you would be Sir Isaac Newton - because that, essentially, is Newton's first law of motion. Perhaps, some such line of thinking led to the formulation of the three laws we know so well. I suspect, however, that the reasons were more fundamental. For example, the physicists say that the conservation of momentum is a consequence of the hypothesis that laws must be the same no matter where we are. They call this symmetry, with the name 'translational invariance'.

Now let us come td the question you have asked. The Earth inherited the motion of the initial cloud of dust and gas from which the solar system was formed. Till it acquired its present orbit, there might have been changes due to collisions and gravitational interaction with other bodies. The Earth keeps revolving because there are no forces acting on it to reduce (or increase) its speed. Friction with the residual inter-planetary gas and matter is minimal. The collisions with meteorites and comets are also not serious enough to make a visible change. It cannot but keep going. It does not need any force to do that; forces are needed only to accelerate or decelerate.

Strictly speaking, what I have said is not quite correct. The Earth is being continuously accelerated due to the gravitational attraction of the Sun. However, that force is nearly perpendicular to its direction of motion. This acceleration does not change the speed of rotation but only the direction of motion in such a way that it keeps the Earth going around the Sun.

104. Why do we experience visual and auditory disturbances on our TV sets when a motor vehicle passes by?

The present day world is full of artificially produced radio noise. This comes from most electrical appliances, transmission lines and, of course, from the large number of transmitters around the world, including radio stations, TV transmitters, cordless telephones and cellular phones. Many of these transmissions can be received by our radios and television sets if the frequency matches and the strength of the signal is above the threshold of reception. It comes in mainly as noise, except when we are tuned to a certain frequency. So why do we get disturbances (which is just another name for radio noise) in all the channels of the TV set when a motor vehicle passes by? Internal combustion engines utilising petrol use spark plugs, which are fired by the spark in the distributor box of the car engine. A spark is a sudden generation of high current. It is an inherent feature of electromagnetic theory that a changing current leads to emission of radiation. The spectrum of the radiation depends on the frequency of change of current (indeed, that is how transmitters are adjusted to emit waves of a specific frequency). However, a spark produces radiation over wide range frequencies. All channels are susceptible, and a disturbed reception is therefore the irritating result.

There is a solution. A condenser across the spark gap reduces the oscillation in spark current and hence the noise. There is another source of disturbancethat has a similar origin; a lightning strike between nearby clouds or worse, between a cloud and the Earth. Disturbance at this time is both acoustic and electrical.

At this time, I cannot resist referring to another disturbance that sets the lower limit of the strength of the radio signal we can detect. During periods of no TV signal transmission, random "jumping" dots appear on the screen, accompanied by some audio

noise. It is exciting that much of what you see and hear at this time is due to the 'cosmic background radiation', which, according to majority scientific opinion, is the "whisper of the creation of the Universe'! The high-energy radiation of the original hot fireball connected with the origin of the Universe has cooled down to microwave frequencies due to expansion of the Universe.

105. Why do our taste buds get affected during periods of nasal congestion?

When we have a cold or our nose is blocked, our world-view changes. Nothing looks or feels good. You are not in pain, sometimes do not even have a fever, and nobody takes your sickness very seriously. You yourself become apologetic about your ailment and dismiss it by telling every one 'it's only a cold'. But changes have occurred within you. Since I am not an expert in this field, I can only provide an educated guess as to what may be happening. I suspect that the swelling and blockage of passages in this part of the anatomy must also interfere with the efficiency and fidelity of the message transmission channels to the central nervous system in that neighbourhood. Smell and taste are amazing capabilities; sometimes, only a few specific molecules are needed to activate receptors to send a signal to the brain, which then gives us a sensation of specific smell or taste. Oftentimes, triggering of a combination of receptors provides the required specificity. Smell is probably a more sophisticated sensory perception than taste. That may be the reason that a blocked nose plays havoc with the senses of both smell and taste. Some components of taste are also derivatives of smell. To test this, do an experiment. Cook or order some thing that you really like. Then sit down and eat it all with your nose pinched closed by a clothes clip. Did the taste measure up to your expectation? Probably not.

This seems a reasonable answer to me; it may not be absolutely correct or complete. Remember, this is still an area of intense investigation.

106. How are scientists able to prove that, because of the phenomenon of persistence of vision, images are retained on the retina for l/10th of a second?

A movie camera takes 24 frames of a scene every second. When these frames are projected before us (again at 24 frames per second), all motion seems fluid. We do not even realise that we are actually seeing slightly different still photographs every 1/24th of a second. The blank screen during the time interval between one frame and the next is not noticed because the image of the first frame upon the retina does not fade out significantly before the next one comes along. It is clear that one way of estimating the duration of vision persistence would be to reduce the number of frames per second and see where we begin to notice a flicker.

Incidentally, television pictures also flicker at the rate of 24 frames per second. The frame is not projected in one piece as in film projection. Each frame is made by a travelling spot, which makes scan lines, one below the other; 624 such scan lines together make a frame. The frame remains intact during the blanking period (due to another kind of persistence, this time of the phosphor screen of the TV set) when the spot jumps from the end of the bottom line to the beginning of the top line. It is truly amazing that a device such as an ordinary TV set works so reliably.

107. Why do car wheels often seem to be revolving in the opposite direction on the movie screen?

Let us picture a wheel, any wheel, with a prominent red mark on the rim. If we see this mark move in a clockwise direction, we will say that the wheel is also rotating in that direction. Let this wheel rotate, say, once a second. This would mean that every one second, the prominent mark would be seen at the same spot. So if we were to infer the motion of the wheel by taking a series of photographs every one second, we will come to the conclusion that the wheel is stationary! This would also be true if the pictures are taken at times that are multiples of one second. If, on the other hand, the pictures were at intervals less than a second, say three quarters of a second, the wheel would not have completed a full rotation between two pictures. The successive pictures would suggest that the wheel is slowly rotating in an anti-clockwise direction. It would, of course, appear to move in the clockwise direction if the interval between pictures is slightly more than a second. When we shoot a movie, we are actually taking 24 pictures a second. Depending on the rotation period of the car wheel, it can appear to be rotating clockwise or anti-clockwise. You would have noticed in the movies, that when a car is slowing down or speeding up, the apparent direction of rotation of the wheels shifts back and forth from clockwise to anti-clockwise; do not believe every thing you see in the movies!!

108. How exactly does a gust of wind blow off a candle flame?

When a candle is lit, the wax vaporises. The heat makes the vapour rise. The heated air also rises and draws in fresh air from below and from the sides. The candle flame is produced due to the chemical reaction or burning of the mixture of the hydrocarbon vapour from the candle and air. A gust of wind would disperse the vapour and the reaction would cease. Yes, it's true that there can be no combustion without air. But if the air becomes a hurricane, the vapour created by a small candle is blown away much faster than it is created and the reaction would cease. On the other hand, a forest fire or a piece of burning wood or coal presents a different scenario. Here, the heat source is not in the air but on the coal or the wood that is burning; this source is not dispersed by a strong wind.

109. Why does it get cooler at higher altitudes, even though we are a few thousand feet closer to the Sun?

Air is not heated significantly by direct radiation from the Sun. The atmosphere is nearly transparent to wavelengths of radiation at which solar emission is concentrated. The heating of the Earth occurs at the surface, over land and sea. The atmosphere gets heated through contact with ground and the subsequent phenomenon of convection, namely the rise of the lighter, hotter air. This leads to churning of the atmosphere, because the surrounding (cooler) air rushes in to the place where the ground heat has set up an upward convection. As you go to higher altitudes, the air pressure reduces; this is a simple consequence of the fact that there is less weight of air above. The rising air coming to regions of lower pressure, therefore, has to expand. This lowers the

temperature. There is no escape from that. Air on the mountains has got to be cooler because there is less air above! But there is more to this story. What 1 said above is not quite correct, namely that the air gets heated only because it is in contact with the hot ground or the warm sea. The hot ground also emits radiation, which is at wavelengths longer than the bulk of solar radiation. This is the infrared, also called heat radiation. The total amount of energy radiated at these wavelengths out into space must be the same as that received from the Sun. This energy would escape out to space directly if there were no atmosphere. That would be true to a large extent if the atmosphere did not have constituents like carbon dioxide and other molecules with more than two atoms. Since the real world does have such gases in the atmosphere (and luckily for us, at the right concentrations), the heat radiation is absorbed in the air and keeps the temperature in a comfortable range for us. Because of carbon dioxide and other such gases, the atmosphere works like a biased blanket. It lets in the solar energy but does not allow the heat energy to escape till the temperature is raised to a level suitable for us. Now you can understand the concern about the increasing levels of carbon dioxide. If we have too much of it, the blanket may make the Earth much too warm and tilt the climate in an unpleasant direction.

This answer is becoming a bit too long but I must go on because some of the statements I have made are subject to qualification and may not be true at all places in the atmosphere (indeed, it is caveats like these that make the discipline of atmospheric science simultaneously exciting and frustrating). For example, it is not universally correct to say 'the lesser the amount of air on top, the colder it gets'. Above the level of tropo-pause, which at our latitude is at a height of about twenty kilometers, the influence of what happens on the ground stops, and the temperature starts rising slowly with altitude. This is the region (the stratosphere and above that the mesosphere) where the energetic radiation from the Sun, such as soft and hard ultraviolet, has dominance. This radiation breaks up air molecules and an unusual type of atmospheric chemistry comes into play. A significant consequence of that is the birth and death of the ozone layer, whose existence is believed to be crucial to the wellbeing of life on the planet. But we will leave discussion on this topic for another occasion.

110. According to Newton's laws of motion, the velocity of a body does not depend on its mass, yet in practice, a heavier substance takes lesser time than a lighter body to cover same distance under gravity. Why?

The first part of your question is a bit misleading. According to Newton's laws, the acceleration of a body on application of a force is inversely proportional to its mass. With the same force, you can throw a cricket ball much further than a heavy boulder or a motorcar. Now think of a large body broken into ten pieces of mass m. The force of gravity on each of these pieces would be equal to m x g, where g is the acceleration due to gravity. The force on ten of these pieces tied together would be 10 x m x g. The acceleration due to gravity of each of the parts would remain the same as that of the conglomeration of all of them, namely g. If the acceleration is the same, the velocity after any instant of time will also be the same. Therefore, it is not true that heavier objects fall faster under the force of gravity. Galileo was the first to demonstrate this. You can do the experiment yourself; throw a marble and a cricket ball from the first floor of a building

and record their time of descent. Strips of paper, and other light objects seem to fall much slower, but that is due to air resistance.

111. How is an aircraft protected from lightning while in the air?

Thunderclouds can be identified, and the first precaution is to ensure that the aircraft stays away from these highly charged clouds. Aircraft are fitted with conducting brushes at the tips of wings and the rudder to ensure they stay close to the electrical potential of the air mass in which they are flying. The electrical potential in the atmosphere varies significantly as a function of altitude. In addition, just the movement of the airplane through the air mass can be fast enough to produce electrostatic charge. This charge must be continuously dissipated. In comparison with a large cloud or even the ground, an aircraft does not appear an attractive target for a lightning bolt. It is, after all, fairly well insulated from the ground. Even if there is high current through the skin of the aircraft, the highly conducting metallic construction ensures that passengers are protected from the effect of electrical activity outside. Communication system and gyros could be affected. Nevertheless, should an aircraft be unlucky enough to lie in the path of a discharge, it could suffer serious damage. I have a feeling that more severe damage is likely to arise from the explosive expansion of the air in the vicinity than through any heating or charring. But I might be completely wrong. The chance of an accident appears greater than the actual observed incidence. This must be a reflection of the precautions taken by pilots.

I might mention yet another hazard of atmospheric electricity. In spite of the brushes at the tips of wings, an aircraft can accumulate significant electrical charge on its body prior to landing. Sparks or discharges must be prevented. In the earlier days, airplanes used to deploy a metal chain that trailed and touched the ground before the wheels of the plane did. Modern aircraft use tyres that are made of conducting rubber.

112. Why do stars twinkle and the planets do not?

Starlight passes through the atmosphere before reaching us. If the air above us were a passive, well-behaved and completely homogenous medium, we will not have any twinkling. Fortunately for us, our atmosphere is active and vibrant. Air masses are always on the move. It is natural, therefore, that there would be pockets of slightly higher density, and others of slightly lower density, flitting around. Starlight passing through these pockets is minutely deflected hither and thither. To an observer, the star will seem to come into view and then disappear, many times a second. We poetically refer to this phenomenon as twinkling.

On the other hand, planets are not point objects like stars. A spatially extant bundle of rays comes to us from various parts of the planet surface and there never is a time when all the rays are bent out of our eye. Therefore, where planets are concerned, we do not see any twinkling. Stellar twinkling actually provides us a probe to study the characteristics of in-homogeneities in the atmosphere.

113. A big fan is attached in front of a moving car, and the motion of the car sets the fan in motion. Could this motion be converted into energy that could be fed back into the system, possibly running the lights or increasing fuel efficiency?

I am sorry to say that this is not a very bright idea. We do extract and utilise some of the energy we use for running the car and we do this in rather elegant ways. We keep the battery charged so that it can be used to start the car and to play the radio and the music system even when the car engine is not running. We also use it in the car engine for circulating the water of the cooling system, operating the radiator fan and for driving the air-conditioning system. You must have heard people remark how much the petrol consumption increases when the car runs with the air-conditioning on. Think of an airplane using a propeller engine. The plane moves forward by pushing the mass of air backwards. If you were to install a large fan in front and try to produce enough energy to drive the plane, you will end up arresting it in mid-air. No, you cannot get energy for nothing and use it for something else. No perpetual motion machines are possible.

114. How do birds manage to sit on a live wire and still not get electrocuted?

When a bird sits on a wire, little current flows through it because it is not in contact with either the neutral wire or the ground. Some charge transfer would take place, but it would be of a kind you would get when you use a continuity tester for finding out whether a certain power point in your household supply is “live” or not. You must have noticed, however, that on occasions a large bird is unlucky enough to sit on a wire and simultaneously come in contact with a loosely-hung neutral wire. It then gets a lethal shock, and sometimes even disrupts the power supply.

115. When comets enter the Earth’s atmosphere, they burn up. But when space shuttles re-enter they do not. Why?

Meteorites and comets are not interested in landing unharmed at the surface of the Earth. In spite of their random and uncontrolled entry, many a time pieces of meteorites do escape complete annihilation during their fiery trip through the atmosphere. The space shuttle, on the other hand, is brought into the atmosphere along a controlled and precisely calculated glide path to reduce heating due to friction. In addition, ablative coatings that dissipate heat through high-temperature sublimation protect the critical surfaces of the shuttle. These coatings might be made of a ceramic or composite material.

We all remember the tragic accident involving the Challenger shuttle during re-entry. It burnt up because of the damage to its heat shield due to a mishap during launch.

116. Why does a soft drink “fizz” when opened?

Bottled or canned soft drinks contain carbon dioxide dissolved under pressure, with the precise purpose of providing the fizz when the drink is imbibed. On opening the container, the pressure is released and the liquid can no longer keep a large amount of carbon dioxide dissolved within its fold. The gas escapes with a fizz. If we do not wait too long, the drink remains fizzy enough to tickle our palate. If we do wait, we are left with just a rather ‘flat’ drink, nothing more than sweet water. The technology of

carbonation of drinks has made a lot of money for some enterprising people and corporations.

117. Why is the boiling point of water lowered when pressure is reduced?

As the temperature of water is raised, its vapour pressure increases almost exponentially. The temperature at which the vapour pressure reaches the atmospheric pressure is the boiling point. Additional supply of heat does not raise the temperature any further. At low atmospheric pressure, the temperature at which the vapour pressure equals atmospheric pressure is obviously lower, and is the reason why water boils at lower temperature at high altitudes. The pressure cooker we use every day in the kitchen employs the inverse principal. Since the cooker is sealed, the pressure inside rises to higher than the atmospheric pressure. The temperature of water can therefore rise beyond 100 degrees centigrade without being brought to a boil. This leads to faster cooking of food. Remember that the pressure is not allowed to rise beyond a certain level. This is the function of the weight on the nozzle on top of the lid; the weight lifts and lets out some steam if the pressure increases beyond a prescribed safely limit. This is usually set so that the pressure inside is slightly less than twice the atmospheric pressure at sea level - which is about one kilogram per centimetre square.

118. Why do surgeons wear only bluish-green apparel?

Beats me. But, on the other hand, why not? There are not too many colours they can choose from. Red is clearly out, for obvious reasons. White would be okay. Indeed, it used to be the popular “colour” sometime ago, but it shows dirt and stains so prominently - smudges of you-know-what would stand out like bright lights. Green is quite a pleasant colour; it does not soil easily and was perhaps promoted by some powerful medical supply company in association with a fabric manufacturer, and in collusion with some medical association. In any case, surgeons cannot be seen wearing the same colour as ordinary doctors and nurses!!

119. Why does the smoke from a burning cigarette rise vertically to a certain height and then dissipate?

Let us look at the two parts of this question separately. Firstly, let us consider why the smoke initially rises. The smoke is produced when the cigarette is lit; the fire and heat ensure the resulting gases are hot, as is the contacting air. Hot air moves up due to convection; it is lighter than the surrounding cold air. That is why you initially see the smoke moving up. But clearly, this cannot go on. Mixing with surrounding air leads to cooling, and the smoke particles are subjected to the random motions of pockets of air and its molecules, a process referred to as “dissipation”. The cigarette smoke, therefore, does not have any long-term supremacy or right of way.

120. Is it true that we cannot fold a piece of paper more than eight times, no matter what its size?

A simple answer to this question can be provided through actual demonstration. Every time you fold a paper, the number of leaves is doubled. So, as you carry on folding, the number of pages becomes 2, 4, 8, 16, 32, 64, 128, 256... Let us stop, because when we've folded the paper 8 times, its 256 pages thick! This is equal to the number of pages in a fairly thick book. It would be impossible to fold it once more. The statement therefore stands proved; you cannot fold a paper more than 8 times. But the question is, why not? I have given this some thought. When you fold a thick stack of paper, the outermost sheet needs to cover a longer stretch than every other sheet. If the stack is a result of successive folding, we have a situation where part of the original paper is being made to stretch longer than the rest. Paper may be delicate in many ways, but it does not stretch or break easily. Conduct an experiment along with a friend. Take a piece of paper from your notebook. Roll the two opposite edges squarely onto two pencils. Hold on to one of the pencils and let your friend take the pencil at the opposite end. If the paper is dry and the two of you pull exactly opposite to each other, chances are that you will not succeed in stretching or breaking it. You can tear paper easily, but to stretch or break it requires a great deal of effort.

121. Why do we see water droplets on a cold glass bottle?

The water which forms the droplets could obviously not have leaked out of the glass, since glass is impermeable. It comes from water vapour, which is contained in the air that touches the glass. Water vapour is a colourless gas, not ordinarily visible. The amount of water vapour that air can hold depends on its temperature. As you lower the temperature of air, it approaches the saturation point, after which the vapour condenses into liquid water. That is what causes dew on cold nights, rain drops high up in the atmosphere and water droplets outside a cold glass.

122. If a glass is filled with water to the brim and a piece of cardboard is placed on the glass, why does it stay stuck even when the glass is inverted? Why does the water inside not push the cardboard down?

In the experiment you describe, there is no air inside the glass. The pressure of the atmosphere can support a column of water over 10 meters tall; if the seal is good, the water is secure inside. Pushing downward, we have the weight of about 15 centimetres of water per square centimetre (that is about 15 grams per square centimetre); on the other hand, over 1000 grams (the weight of air over each square centimetre) is supporting the column of water!

123. Why does a finger stick to chilled ice tray?

The ice tray in the freezer compartment of a refrigerator is usually at a temperature well below the freezing point of water. When you touch a metallic (usually aluminium) ice tray, the tip of your finger is quickly cooled below freezing point. Your touch might melt a bit of frost on the tray, which then quickly re-freezes as the heat flows out to the cold tray. Also, there is always a little moisture on your skin, which would freeze upon contact, thereby bridging your finger and the cold tray.

124. Why does an iron object feel cold to the touch?

This is true only during cold weather. If a piece of iron is lying out in the Sun during the summer, it feels very hot. Iron is a reasonably good conductor of heat. If it is colder than the temperature of the human body, it can draw in a lot of heat. The reverse is true if it is hotter than the body temperature. This is not true only for iron, but also for any object made of metal. One has to be particularly careful while touching metallic objects such as outdoor tools, railings and machines with bare hands in severely cold climates.

125. When I powder pieces of different coloured glass, the resulting powder always looks white, irrespective of the colour of the glass I started with. Why should this be so?

You are correct in your observation, and the phenomenon is indeed intriguing. The answer to this question takes an important clue from the answer to a previous question, as regards light scatter. Such scattering is mandatory whenever light passes from one medium to another of a different refractive Index. When I powder glass, I am creating more and more "surface". In the ultimate limit, I am left with only the surface; there is no "inside". The scattering at the surface is not respectful of the colour of the glass I started with; the scattered light is the same colour as the incident light. So when viewed in white light, the powder looks white.

Incidentally, a similar argument explains the fact that, irrespective of the colour of the soap, the colour of the foam (or suds) you make by dissolving it in water is always white.

126. Why does a piece of chalk (which is not a perfect cylinder) exhibit motion on a curved path? I imagine that moment of inertia and the offset centre of gravity plays a role in the torque formation. I would appreciate a detailed physical and mathematical explanation.

I understand your question in the following way. When you place a chalk stick horizontally on a slightly tilted plane, you find that it does not roll straight down but describes a curved path. If I am correct in this interpretation of your question, the answer could be the following:

The force on the horizontal chalk stick is that due to gravity, of which the component normal to the surface of the plane is cancelled by the reaction of the plane, while the component parallel to surface wants to drag the chalk stick downwards along the surface. If the frictional force were small, the chalk stick would just slide down horizontally. This could be checked by using an oiled steel surface or, for that matter, a glass surface. But for a chalk stick on a normal dry surface, the friction is high and the tendency to slip immediately produces a rolling motion, for which the friction is negligible. When the chalk stick is rolling then, for each rotation, the thicker end of the chalk will travel a greater distance than the thinner end and this will automatically produce a curved path. Because of angular momentum, the stick will go a little beyond the vertical and then swing back to a vertical position. It will then become stationary unless the tilt of the surface is increased, in which case it will slide vertically down.

127. Christopher Columbus discovered America. Who discovered India?

One can give a possible answer to the first "finding", by humans, of most parts of the Earth. There is strong evidence that our species evolved in Africa about half a million years ago. It might have spread out to the rest of the world in several small waves. I am sure it did not take long to populate an empty India. It is difficult to name a leader who first brought a group of humans to India. It must have been so early during the spread of humanity over the planet that a date in written or oral history cannot be found. India can therefore be considered one of the primeval countries of the world. Some of these questions are still being debated, with newer dating technologies (including DNA dating) adding fresh Insights.

It would be erroneous to say that Christopher Columbus *discovered* America. It already existed. There were people living there, some of whom had developed a great civilisation - far more advanced than any In Europe. The Europeans destroyed this civilisation. The so-called ages of discovery and exploration were the periods in human history when expeditions from some nations were sent out, primarily riding on the spirit of curiosity and adventure, but also to seek out and plunder the wealth of the world. They became the "discoverers". They also became conquerors and colonisers.

128. How does a pencil eraser clear all our mistakes on paper?

I wish an eraser had the power to clear up all our mistakes and correct all our follies. Were that true, I would always write with pencil on paper!! More seriously, the question is perhaps concerned with the fact that while an eraser can erase pencil marks, It is unsuccessful with ink. Pencil 'lead' is actually graphite. When we write, we spread a layer of graphite on the surface of paper. This layer binds to the very top surface of the paper, but the graphite is not deeply impregnated into the paper. As we rub, the eraser loses a thin layer of rubber that picks up the graphite particles, along with a very thin layer of the paper itself, leaving it clean. When we write with ink or a ball pen, the Ink soaks into the body of the paper, which cannot be taken away by as gentle an erasing action. You can, of course, use a more abrasive eraser that will remove a deeper layer of the paper, along with the ink impression. This does damage the paper visibly.

129. Why do certain elements change colour when exposed to a flame?

The heat of the flame excites the atoms to higher levels. Light is emitted when these atoms de-excite and transition to lower levels, such as the ground state of the atoms, The energy states of different atoms are primarily determined by the charge on the nucleus, namely the atomic number. Therefore, the photons emitted during de-excitation carry, in a sense, the signature of the atom. This is the basis of the science of spectroscopy. It is through precise measurement of wavelengths of light received from stars that we can determine their chemical composition and temperature. Professor M. N. Saha did the seminal work in this connection.

130. Can a mirage be photographed?

A mirage is a real physical phenomenon in which the light rays coming from a distant location towards the ground are bent upwards into your eyes. This makes you see the 'reflection' of the sky, trees and structures, giving you the Impression that there is a pool of water there. Light bends because the refractive index of the hot air close to the hot ground is lower than that of the upper layers. The 'reflection' is as real as it would be if there was an actual pool of water. Therefore, a camera will also see the same, and would capture the image of the mirage.

131. When it is possible to make one-way see-through glass, why is it not possible to do the same with sound? I beg your pardon if my question sounds naive or silly.

I thank you for asking this question, because it appears to have resulted from original thought and curiosity. Let me see if I can provide a credible answer. Firstly, when we talk of one-way see-through glass, we are thinking about a room with a glass window or wall through which we can see only in one direction. Such rooms are often used for identification of crime suspects. The witness is on one side of the glass while the suspects are in a line-up on the other side. If the suspect's side of the room is brightly lit and the glass partition is partially silvered, the suspects will not be able to see the witness. The irises of their eyes will narrow while adjusting to the bright light, and the faint light coming through the silvered glass will not be perceptible. On the other hand, the witnesses in the darkened room will be able to clearly see the suspects. That is the one-way-ness of the arrangement. It relies on the fact that in the presence of a large optical signal, our eyes adjust in such a way that lower level signals fall below the perception threshold. We have a familiar example; we do not see stars during the day because the atmospheric window becomes bright. The atmosphere seems to act as a discriminator!

The question is whether this kind of discriminatory perception exists for our sense of hearing as well. Eyes and ears may be somewhat different sensing organs, but there is no question that small sounds get easily drowned out when loud music is being played. You may be able to eavesdrop on the conversation of two people from outside the room, but only if there exist no other loud sounds nearby; you will hear much less (or nothing) of their words if a marriage band (or a three-wheeler blaring election propaganda) goes by. In that sense, all rooms are one-way hear-through systems. This is particularly true if the room is partially sound proofed. While loud noises in the veranda would be disturbing to those inside, the soft music playing inside would not be heard or enjoyed by a garrulous crowd outside the room.

132. Consider a piston, fitted inside a cylinder of infinite length (both perfect non-conductors of heat), with an ideal gas inside the cylinder. Suppose the system is taken to outer space (free of influence of gravity and other effects), will the gas inside expand, thereby pushing the piston to infinity in order to balance the inside pressure with the vacuum outside?

This is an interesting thought experiment Like you, I shall also assume that the friction of the piston with the walls of the cylinders is zero. This means that the slightest force will move it howsoever little. For a while, the piston will go on moving, as you suggest This might be a long while. But ultimately, another force will begin to dominate. This is

the micro-gravity between the molecules of the gas, the cylinder and the piston itself. In so-called "gravity free" space, you cannot abolish the gravitational attraction between the components of the instrument itself, including the molecules of your perfect gas. It may turn out that ultimately your instruments become the nucleus for gravitational accretion of particles, molecules and inter-planetary and inter-stellar dust. Happenings might be forgotten and billions of years later a new star might be formed! What you have done through your experiment is to introduce a non-homogeneity in space, in the sense that a gradient of gravity is created through mere existence of your apparatus. Your apparatus might become a nucleating core attracting intergalactic matter! The origin of galaxies, stars and much else, including the rings of Saturn, is believed to be very similar.

133. What should we do to concentrate on studies when exams are around the corner?

Shed your fear and start studying. If you concentrate more on understanding than on memorising, you will end up doing both. The pressure would disappear.

134. Can electric charges and magnets distort space the way gravitation is said to do?

After Einstein, gravitation has acquired a special role. Gravity defines the structure of space. All matter and energy, no matter what its charge or quantum number, is subservient to gravity. It has only one sign; there is no negative gravity. This is not true of electric and magnetic fields. They belong to a different species of fundamental forces. There is a quest to get to a theory that will encompass all forces of nature. This has been nearly accomplished for the three other forces. Gravitation has still to be brought into this unification.

You might think about your question in another way. As the mass increases, its gravitational force goes on increasing. If the charge were to increase, it would disperse very soon because of mutual repulsion of the particles. You cannot go on increasing the charge and have a stable configuration. And if we add particles of the opposite charge in equal number, the mass would increase but the net charge remains zero. The large-scale electric field disappears.

135. How do flies die? I have never seen a dead fly.

A fly could die in many ways. You might swat it. It might come under your foot, even though it is very unlikely. It might fall into a cup of milk or get trapped in honey. I suppose these are not the answers you seek. Perhaps you want to know about the life span of a fly. I have looked through some literature and I am overwhelmed. There are so many species of flies. Some rather benign, in the sense that they only suck juices or lick on things they like. There are others who sting and bite. But I will like to come back to your question. It seems they do not live too long after reaching adulthood. Life spans vary from weeks to months, and at the very maximum a year. If there are so many flies dying all around, where are their dead bodies? The reason we don't see their corpses is that they are not left around very long; very soon, insects descend on them and finish them off. Ants drag them away if they cannot consume them on the spot. Indeed, there is no dearth

of sanitary workers - insects, birds and of course, bacteria. A dead fly, like dead anything, is high quality food for many species.

136. What is the white thing in a cube of ice?

I think that "white thing" is primarily comprised of trapped air bubbles. Water always contains some dissolved air, and some of the air bubbles do not escape during the freezing process. If the ice cube is made under low pressure, the dissolved air would escape and we would get clearer ice cubes. Perhaps starting with freshly boiled water might also produce clear ice cubes. I know that clear ice cubes are commercially available. I do not quite know how it is done. Why don't you follow my hunches and see if they are correct? I have neglected to mention the fact that water may have other impurities too.

137. The Sun is a hot ball of gas. Why does the gas not escape?

Each molecule of gas is also subject to the force of gravity. The Sun is a very massive object, so its gravity is very high. A molecule will be able to escape the Sun only if its velocity is higher than the escape velocity. Even at a temperature of about 6000° C on the surface, the random velocity of the molecules is less than the escape velocity. That is the reason the hot gases normally remain imprisoned on the Sun. This argument is very general. The mass of the Earth is such that at the temperature of its atmosphere, most of the molecules remain confined; otherwise, we would have lost our atmosphere. Hydrogen and helium molecules do tend to escape into space since their velocities are rather high at existing temperatures.

There are occasions when some of the gases near the surface of the Sun get heated to exceptionally high energies because of special electromagnetic phenomena. That leads to a wind emanating from the Sun and other stars. You must have heard of solar flares and sunspot activity. Though material is lost, the loss is relatively small in the context of the total mass of the Sun.

138. How do astronauts write in space where there is no gravity?

Ordinary fountain pens would have a problem because, in the absence of gravity, the ink may not touch the narrow capillaries in the direction of the nib. But who uses a fountain pen these days? Pencils would work as they do on the ground. Astronauts in space do not live in a vacuum. Air pressure is still available and capillary action would be still operative. Feltpens, therefore, should have no problem. Many other ways can be devised; the pens can also have toothpaste-like ink containers that could be compressed to ensure that the ink moves towards the writing ball! That is the most efficient way of dispensing food, or ink, in the weightless environment of space.

139. Though hydrogen and oxygen are present in air, why does it not lead to the spontaneous formation of water?

Firstly, there is very little hydrogen present in our atmosphere. What is produced through various biological and chemical processes quickly escapes to the top of the atmosphere. But let us ignore this fact for a moment. The reason that oxygen and hydrogen do not rush to embrace each other to form water is somewhat similar to that which keeps kerosene, petrol or even wooden household furniture from bursting into flame in spite of the presence of oxygen. It is true, of course, that an oxygen-hydrogen mixture that is sufficiently rich in hydrogen is very explosive because it takes the tiniest of sparks, which could even arise from static electricity, to start a fire. But in our atmosphere we do not have the requisite amount of hydrogen.

140. How do whales and dolphins sleep without drowning?

Whales and dolphins are mammals. They do need to breathe air like we do. One might imagine that the lungs of whales would be enormous. Considering the whale's size, they are not, but they seem to be used rather efficiently. Human beings normally use only about a quarter of their lung capacity when they breathe in. Whales do much better. I am told that their blood can also store more oxygen than ours can. This means that whales have a rather large storage capacity for air in their lungs and can use the stored air for much longer than we can. When whales dive into water, their heartbeat slows down. In other words, they can live much longer without taking a fresh breath of air. All the same, I cannot imagine that they would go without surfacing for half a day or the whole night, if they sleep as soundly as we do. But they can stay under water for periods as long as two hours. This demands that they meet the requirement of sleep by short snoozes. It is suggested that whales need to use their brains to decide when to take in air - this function does not happen automatically. I am an ignoramus in this area but I suspect that even while asleep, they manage to come near the surface to gulp some air. As in us and in other living things, a lot of functions that are vital to life must keep operating when they sleep. Surely, a lack of oxygen would wake them from their snooze and make them rush to the surface. After all, even in the presence of air, breathing does require a proper functioning of lungs, beating of the heart and circulation of blood. Perhaps putting their blowholes near the surface is an operation programmed into their survival strategy. So my hunch is that they stay close to the surface even during short periods of sleep. As I mentioned earlier, they have, in any case, devised a strategy of not sleeping for long stretches at a time as we do.

141. How is it possible for insects and spiders to walk on water or on the walls?

Tiny Insects can walk on water because of the phenomenon of surface tension. The unbalanced intermolecular force makes the surface behave like a stretched membrane. The classical demonstration of the carrying capacity of this membrane is to gently lay flat a shaving blade (to ensure that the weight per unit area is kept low) upon the surface of still water; the blade does not sink. The blade is heavier than an equal volume of water and would surely sink if the force of surface tension were absent. Thus, one can easily understand why little insects and larvae can float on the surface of water. This fact Is responsible for the enormous diversity of living things in and around the marshlands. Amongst other things, this phenomenon has a central role in defining the manner in which mosquitoes breed.

As regards the ability of insects to walk on walls, several explanations are provided. The most popular is the hypothesis that such creatures have suction cups on their feet using which they can stick to walls and ceilings. Some recent investigations indicate a special construction of the feet; thousands upon thousands tiny, protruding hair-like projections stick to surfaces due to good old molecular forces. In essence, we are talking of surface effects between the structure and material of the feet and the surface of the wall, or the ceiling.

142. In mid-afternoon, the Sun appears bright yellow. In the evening and at dawn, it turns red. Why?

In the evening and at dawn, the Sun is low on the horizon. As a result, the Sun's rays travel a relatively longer distance through the atmosphere before they reach us. Therefore, scattering of light by air molecules occurs to a greater degree. This scattering is selective. Waves of longer wavelength scatter much less than those of shorter wavelength. As a result, close to dusk and dawn, the light we receive has lost most of the violet, indigo, blue and green components on the way. Yellow, orange and red remain. As the Sun dips close to the horizon, the yellow and orange parts are also progressively depleted and we are left mainly with the red colour. Since the degree of scattering is inversely proportional to the fourth power of the wavelength, the violet colour is depleted nearly 16 times more than the red. This same differential scattering gives us our blue sky. I hope you recall the VIBGYOR (Violet, Indigo, Blue, Green, Yellow, Orange, Red) formula for remembering the order of various colours as graded by increasing wavelength.

143. What is the principal reason that life exists on Earth?

It is one of those questions where many answers may be proposed and none of them may be correct. I tend to believe that with the kind of conditions that came into existence on Earth, since it was born, life was inevitable. On the other hand, an equally acceptable answer would be that life was a highly improbable event. The discovery of life on other planets may sway this argument one way or the other, but currently, as you know, "Earthly" life is the only example we have. The story of all the life we know of is written in the same language, using a small number of genetic alphabets. Also, there is indisputable evidence (for me, at least) that the process of evolution has given rise to the tremendous diversity and survival of life we see on the planet. There are a lot of people who would say that the whole Universe was conceived in order that a small speck of dust (namely the Earth), orbiting an average star (namely the Sun), could spawn living creatures; and also that these self replicating, living creatures would, after an adventure of 4 billion years, produce a species, one of whose children would stand up and ask "What is the reason and purpose of life?" I personally cannot stomach the idea that we were initially thought up as the reason for all this extravagance. Even if we are accidents, I do not mind. I am grateful regardless, and the fact that my existence may be accidental makes me feel no less special.

144. Why do we see shimmering on the road during a very hot day?

The effect you see is popularly referred to as a mirage. Besides on hot roads on a summer day, this phenomenon is also common in the desert. The physical reason for this observation is the following. The Sun does not heat the air mass directly. The surface of the Earth is heated first and the air gets its heat by coming in contact with the ground. The hot air is less dense than the cooler air on top. A ray of light, coming from the sky, a distant treetop or a building, travelling down at a shallow angle is continuously bent upwards and finally suffers total internal reflection. When such rays fall on your eyes, you get the impression that out in the distance, on the road or in the desert, there is a pool of water that is reflecting the sky or other distant objects. Since heating can be non-uniform and the turbulence in the atmosphere can swirl around and mix up the air pockets, the objects often appear to shimmer.

145. Why do things die? Is there a way to make things immortal?

I think your question could be reversed. "How can things, including us, continue functioning for so long?" I do not know of any complex man-made machine that has continued working for as long as I have been alive. Just look at the complexity of the simplest living creature, say an ant or a fly. If some one had proposed, even to God himself, that process of evolution would lead to the diversity and virtuosity of life we see on Earth, probably even He would have been skeptical. And yet, here we are with our wonderful body machines, ticking away. We are not too particular about the energy source we use - no arguments about whether it should be CNG, oil or coal!! Eat some lentils, fruits, some cereal and a few other things you like and you keep going. No other machine could do that. My heart must have ticked about three billion times and still keeps galloping. Who knows how many intruders have I repelled, and how many others I have befriended while living in the midst of an immense biological proliferation - and all of this has been done automatically, without my knowledge, without bothering me. No maintenance schedules have been required and very few people have descended on me with scalpels and screwdrivers. And I still go on.

But more seriously, your question is still valid. If we can live flawlessly for so long, then why not forever? I believe that death is a planned feature of life itself. It is found, for example, that there are cells into which suicide is programmed. As we go on living, mutations occur on which there is little control - these might be due to environmental effects, chemicals, radiation etc. Perhaps there would be some progress in prolonging life in the coming years. But it would be terrible if humans are permanently stuck in the exuberance of youth, when there are no grandparents who behave like grandparents, when there is no time to brood over and consolidate the stories of a long life. The secret of present longevity is that we are continuously rebuilt. Most of our cells, except for those in our brain, have been replaced many, many times. I wonder sometimes why our brains are not allowed renewal; perhaps that would rob us of our memories, of our feeling of "self, and of "consciousness" that defines us.

146. I've heard that the Universe was created by the Big Bang. What was the cause of the Big Bang? Some say that Time did not exist before the Bang. Is this true?

A detailed answer to this question would fill the pages of a fat book! And even then, many questions would remain. But it might be useful to talk about the basic elements behind the colourful and well-argued mythology of the Big Bang.

After it was found that the Universe has many more galaxies, or island! Universes, besides our own, it was natural to look at them analytically to find out if they were made of the same kind of stuff as our own Milky Way galaxy. Specific elements in the hot atmospheres of stars can be identified through the signatures of wavelengths of the emitted light. Signature wavelengths were actually found, but the wavelengths corresponding to; known transitions were "shifted". The manner of the shift suggested that the distant galaxies were moving away from us. This shift, popularly called the Red Shift, was interpreted as being caused by the Doppler effect. A simple arithmetic operation can convert the amount of Red Shift to a velocity of recession. The distances to some of the nearby galaxies had been estimated by other methods. The measurements done by Hubble indicated that the: Red Shift increased with distance. Since no one still believed we were at the centre of the Universe, the natural explanation was that every galaxy is moving away from every other. In other words, the Universe is expanding. In such a case, entities further away would be receding from each other at a faster rate. This was interpreted as observational evidence that the Universe is expanding like an inflating balloon. Clearly, the Universe would have begun its expansion at some specific time. Indeed, one could argue that there must have been a time when all the mass and energy in the Universe was concentrated in a very small volume, perhaps less than the size of a single particle! It was natural to then consider the moment the Big Bang occurred as the moment of the origin of the Universe! Though there is much evidence for this generally accepted hypothesis, there are also several unresolved questions.

So far, we have used very simple arguments without worrying about relativity. In the world of relativity, we do not talk of Space and Time separately but as four-dimensional Space-Time. In such a scenario, you could argue that "if Space began with the Big Bang, so did Time". There is no point in talking about Time before the Big Bang - Time just did not exist!

I know that all the answers are not contained in this general description. A question frequently asked is "why did the Universe bother to exist, or bang in?" Someone suggested that the Universe might have started just as a quantum fluctuation in the fabric of the Space-Time vacuum. Later, evolution led to the manifestations of the potentialities of this fabric - galaxies, stars, planets, even life and people! Even though we are left with several why's and what's, the quest is in itself exhilarating.

147. How do we define a dimension? How many dimensions are possible and can all of them affect our life in some way?

Let us first consider our ordinary world. If the Earth were a perfect sphere, with no mountains or valleys, not even tides in the oceans, we would be able to give the position of any point on it by giving just two coordinates, the longitude and the latitude. This is because the third coordinate, namely the distance from the centre of the Earth, would be assumed to be constant. In reality, we do have mountains and valleys, we have tides and we have buildings and structures that have height, besides the fact that we also want to

venture to the bottom of the sea and drill holes for oil. So we do need the third dimension. Thus, run-of-the-mill space and all objects therein are very well located by giving just three coordinates. The three axes with respect to which the coordinates are given are orthogonal (at right angles) to each other.

But we also use another dimension to describe happenings in the world. This is the dimension of Time. We want an answer to both - where and when! Till the beginning of last century, Time was considered like a flowing river, the same for every thing in the Universe. And then Einstein happened. The Theory of Special Relativity showed that it is best to think of Time as a dimension of a four-dimensional Space-Time reality. "Now" of the Sun, for example, is separated from the "now" of the Earth by 8 minutes, the time it takes any effect of the Sun to be felt on the Earth, which is the time it takes for light to travel from the Sun to the Earth.

But the story of dimensions does not end here. Mathematicians can construct spaces that have any number of dimensions. You have only to ensure that all the axes are orthogonal to each other in this mathematical space. For example, the present day mathematicians and physicists are working on "string" theories with ten dimensions in an attempt to describe all forces of nature and achieve a unification that has remained the dream of the most adventurous of scientists. The claim is that while theory demands ten dimensions, only four of these become manifest in the real Universe in which we live!

I know that I have gone much beyond what you expected in reply to your simple question. And, as I have often stated in my answers, I do not claim any originality, not even a full understanding. But you asked for it!

148. How does a radio catch signals of different frequencies when the tuning dial is rotated? Also, why can't the radio catch TV signals?

When you turn the knob on a radio, you are changing the characteristic frequency of the circuit inside the radio. In most radios, varying the capacitance of the tuning circuit does this. This characteristic frequency is the natural frequency at which the current in a circuit, consisting of condensers and resistance elements, for example, can oscillate. Turning the knob can change this frequency. When the frequency of the Incoming signal matches that of the circuit, the two resonate and the gain is large. You have then picked up a desired channel.

Resonance is an Important concept in the physical world. When you pluck the strings of a "sitar" or any other stringed instrument, you get a note of a specific pitch. If another stringed instrument tuned to exactly the same pitch is placed nearby, you may find that the string of that Instrument also begins to vibrate, producing an identical note. This is easily seen with tuning forks, often used for tuning pianos; tuning forks are often found in school laboratories. You would have heard the story of Tansen's singing, where his voice was able to crack glass lamps through vibrations, excited by the volume and purity of his voice. This might be only a story, but it is not physically impossible. A resonating element can pick up an enormous amount of energy from an amorphous energy source. Moving to another example, a swing can be raised to a great height if a little push is given in step with its natural frequency. There is a story of a large hanging bridge that collapsed in gusts of wind because the gusts happened to contain frequencies of pressure

change that were in resonance with the natural vibration period of the bridge structure. Modern architects who design tall bridges and other buildings have to keep such factors in mind.

Tuning of the Television channels is done using the same principles as tuning of radios. In general, radios cannot catch a Television signal because, the frequency range is different and the manner in which the signals are modulated with information is also not the same. But the sound channels of Television transmitters can often be picked up by FM radios.

149. Why do waves have crests and troughs?

I think your question has come from your observation of waves in a pond or at the seashore. You would get the same impression if you were to shake a suing tied to a tree on the other end - you would see a crest travelling to the other end and then, perhaps being reflected back. Like the particles of the rope, the molecules of water in the pond also move up and down; they do not travel in the direction in which the wave travels. The word ‘wave’ also implies that at a given point, some parameter increases and decreases with some periodicity, and this tendency propagates. So crests and troughs are implied but they need not be always normal to the direction of propagation. This is so for water waves, waves in a string and also for light and radio waves-these are referred to as Transverse Waves. But this is not so for sound waves (refers to as Longitudinal Waves), for which the crests and troughs are in the density changes of the medium through which the wave travels.

But let me come back to the exact wording of your question. When you throw a stone on a pond, you depress a bit of water, you form a bit of a trough. The disturbed molecules of water also drag their neighbours down with them. But they cannot stay down permanently. This is because physical media have inertia and elasticity.

150. What are the benefits of using GSLV to launch satellites into geostationary orbit?

Communication satellites are usually placed in a geostationary orbit. This is an orbit over the equator at a height such that the period of revolution of the satellite around the earth is exactly the same as the period of rotation of the earth-namely 24 hours. The advantage is that the satellite in such an orbit appears to be stationary with respect to the earth. The communication antennas on the ground can be pointed in a fixed direction without worrying about the rotation of he earth. We already have several such satellites providing communication, including television broadcast and networking services. The demand for such services is continuously increasing. Therefore, we do not need more satellite transponders in orbit. We also need to replace satellites that are close to the end of their lives.

So far, we have depended on European or American launchers to raise our satellites into the geostationary transfer orbit. However, we are now beginning to use our own launch vehicle. Some of the rocket stages and associated technologies already developed for putting satellites in polar orbits around the earth (for remote sensing) were upgraded and modified for GSLV (Geo-stationary Satellite Launch Vehicle). A new rocket stage

using liquid hydrogen and liquid oxygen as added, in addition to other modifications in the launch systems previously developed for polar launches.

Given our track record in this area, it seems certain that we will soon have a full-fledged capacity for launching our own geo-stationary satellites. The flexibility of space communication and Earth observation systems is a remarkable boon for countries like India and we must keep enhancing our capabilities in this direction.

151. Do photons have rest mass? If they do, does QED still hold? Is it true that if light has only momentum and no rest mass, the quantum theory would require revision?

No, photons do not have any rest mass. This is completely consistent with, Quantum Electrodynamics (QED). Indeed, it is generally believed that QED, has been tested to greater stringency than any other theory. No discrepancies have been found.

152. Frequently, when the door to a room is pulled shut, other doors and windows of the room vibrate in sympathy. Why is this so?

When we shut a door with sharp motion, we drag in some extra air into the room. If the room is airtight (or nearly so), this raises the pressure inside. Even a slight pressure shock is enough to rattle windowpanes or doors elsewhere in the room. You must have noticed that when you close the last door of a new car, you have to do it with a bang (employing more force than with an older, more "porous" car) unless you roll down one of the windows slightly. This is because increasing air pressure inside the car resists the closing of the door.

153. Since our body too is made up of atoms, do atomic spectra influence our body in some way?

We are creatures of the Universe, specifically of this planet. All the laws of the Universe are as applicable to us as to the so-called non-living things. Atomic spectra are a consequence of the structure of atoms. It is true that; we live in a sheltered environment, here the light that comes down to Earth without much obstruction has the same spectral range to which our eyes are most sensitive. We are protected from the ultraviolet part of the spectrum by the atmosphere and the ozone layer. The heat radiation emitted by the Earth is partially retained within the atmosphere because the structure and spectra of carbon dioxide and water vapour are suited to absorbing this radiation.

154. What happens if a body moves at the speed of light?

A "body" can do it only if it has zero mass. If you wanted to run at the speed of light, you will have two choices. You could disappear into nothing, and exhibit zero mass. Or you could be arrested trying to steal all the energy supply of the world or more, because that's what it would take!

155. What is a white hole? What is the difference between a white hole and a black hole?

Equations that describe the formation of a black hole would be equally valid if the direction of Time were reversed. In that case, you would be describing something like a black hole bursting out with light matter and energy. This might be termed as a white hole! The only problem is to find a way of reversing Time! As far as I know, while there is definite evidence for the existence of black holes there is none for white holes. Scientists like to speculate and dream - even dream the impossible. You could, of course, say that the origin of the Universe was just one or more white holes bursting forth -just one such explosion if you believe in the Big Bang theory, or more if you conceive of some sort of continuous creation!

156. My question might sound a bit absurd, but I am putting it forward after having thought about it quite a bit. Is there any possibility that humans are a minute part of a large organism, the existence and the dimensions of which are presently beyond our comprehension?

Your wondering is not so absurd. Such thoughts have occurred to several persons. Ecological thinking emphasises a similar train of thought. Our planet is in a very delicate balance. We have just the right fraction of oxygen in the atmosphere. A little more or a little less would not do – at least for the kind of life that inhabits the planet now. The atmospheric composition has colluded with the Sun to ensure that we have an ozone layer to, protect us. The temperature on the Earth is maintained within very stringent limits. It could very well have been hundreds of degrees higher, as on Venus! This is maintained by a fantastic air-conditioning system that works effortlessly, with the involvement of so many features and so many kinds of life. It seems that the balance could easily be tilted in a direction such that we might have a runaway greenhouse effect, the destruction of the ozone layer and much else. Because of all these aspects, it is attractive sometimes to think of the planet as an organism of which we are just a small component. It is not ours to exploit, only ours to maintain for the coming generations. Elimination, even reduction, of bio-diversity might have disastrous consequences. It is possible of course, that the planet will adapt itself to another state of existence in which we humans do not figure. Even though we find it hard to get away from the misconception that all of creation was meant for us, we might be a very brief temporal component of the history of the planet. One hopes that we will not work to make our stay even briefer than what it might otherwise be.

While we are entertaining such thoughts, a subset of such thinking may also merit some consideration. A friend of mine once wondered aloud that each of us might be like a single cell in relation to the whole of human society. The number of humans on the planet is now rather similar to the number of cells in our bodies. In this sense, the whole of humanity might also be considered a single organism - particularly now that Interdependence and the communication systems can keep us in an interacting soup! If so, this organism has a long way to go before it begins to behave like a single being. Furthermore, if some “cells” in the organism become oblivious of the importance and needs of billions of others sharing the same home, our future might not be so secure. I doubt if parochialism of any kind is an enhancing influence in the long run. The dilemma

is that the way we are constructed, we often makes a virtue of infinite parochialism. Otherwise, we would not have had to constantly deal with regional and national conflicts, or the fundamentalist agendas of various kinds.

157. How can sea mammals drink salt water?

It is unreasonable to assume that sea mammals can live on salt water, any more that we can. The first thing that occurs to me is that their need of fresh water should be less than ours, because a lot of water we ingest, particularly during the summer, is used to cool us through evaporation. Clearly, large sea mammals do not need this - when the skin temperature rises, all they need to do is slip down into the water for a while, or splash a bit. Secondly, it is believed that whales can generate their own water by burning food during metabolism. They are lucky to have their own pure water factories. Water is a "waste" product of metabolism that they have learnt not to waste. Thirdly, I would say something about which I am not sure. Could they also have the capability of performing reverse osmosis? By using specific membranes and pressure systems, can they convert salt water into less salty water? After all, selective membranes are essential features of all living things. I have not been able to verify this last bit of information, so consider it just a hunch; it may or may not be correct.

158. What is anti-matter?

The answer to this question could be simple or detailed. I would stay with what I hope is a simple explanation. We all know that an electron has negative charge. We also know that a proton has an equal and opposite (positive) charge. Incidentally, calling one negative and the other positive is only a convention. But this convention already recognises that there is a two-ness to the property we call charge. About seventy years ago, Paul Dirac tried to construct a theory of the electron, and he was surprised that the same equations also described a particle of the same mass but opposite, namely positive charge. If you were to start with vacuum, with no charge or mass, and if enough energy was available, you could create a negative electron along with a positive electron, if the process conserved energy and momentum. The positive electron is now called the positron and is an anti-particle of the electron. The positron was discovered a year after Dirac propounded his theory of cosmic rays: A gamma ray, scattered off a nucleus, created an electron-positron pair. It was clear from then on that we must also have an anti-particle for the proton that will have the same mass but a negative charge. Such particles have also been discovered. It is then clear that as far as chemistry is concerned, there would be no difference between a hydrogen atom made of a positive proton and negative electron and another one made of a negative proton and a positive electron. An Earth made of the elements we know could not be distinguished, by an observer in another solar system, from one made of the very same anti-elements. The two could have exactly the same geology, chemistry and life. The only requirement for a future for either of them would be that they stay away from each other because a contact between them would result in annihilation of both in an enormous ball of energy.

The problem remains, however. If both a Universe and anti-Universe were theoretically possible and if they would have had indistinguishable fortunes, how come

only one was chosen? It is another matter that if such a differentiation had not occurred, we would not have been around. Nevertheless, this question remains one of the most profound concerns of present day physics and cosmology. Are there any deep reasons for the observed asymmetry between matter and anti-matter? If so, what are they?

159. When I move my fingers rapidly from side to side in front of the TV screen, why do I see multiple images?

There is nothing special about your fingers. A pencil will do just as well. In a normal Television, the picture frame is refreshed 24 times a second. That is how motion is perceived. This is also true of motion picture recording and projection. In between frames, is a short period when the screen goes blank. This is the period when the scanning beam of electrons moves from the bottom of the screen to the top so as to start a new scan. Our eyes do not notice the scan or the blanking period partly because of slow decay of light from the phosphor on the screen, but mostly because of the phenomenon of persistence of vision. (Perhaps persistence of vision is also due to another slow decay - namely that of the signal coming to the visual cortex from the sensors at the back screen of the eye!)

Thus, when you shake your finger (or a pencil) in front of a computer or Television screen, it is in effect going across a source of light that varies in intensity 24 times a second. This leads to broken and separated images of the finger. While typing these words, I tried to estimate the number of separate Images I saw while rapidly sweeping my finger across the computer screen. I estimated that every second I was doing four traversals and I saw about six fingers during each passage. So, without any additional equipment, I could say that the illumination of my screen fluctuates about 24 times a second! Try it.

Incidentally, you may also be able to demonstrate, with a similar measuring technique, that the tube light in your home or office fluctuates nearly 50 times a second. This is the frequency of the alternating current (AC) electric supply in India.

160. Is Dark Matter Theory a reality?

Dark Matter is an observation, in the sense that the dynamical features of many aspects of the Universe suggest that there is far more gravity-producing stuff in the Universe than what is visible to us. The part that is not visible Is called Dark Matter. There are several hypotheses floating around to explain this vital discrepancy, none of them fully established. One attractive (though still not fully accepted) hypotheses is that the neutrino might have a tiny mass, say one fiftieth of that of the electron. Since the Universe is probably a veritable glue of neutrinos, their combined mass may be enough to account for the discrepancy.

161. When air is expelled from the mouth in a gentle stream, it is kind of warm, but when expelled under pressure, it feels quite cool. Why?

Our body temperature is usually higher than that of the ambient atmosphere. The air that we let out while exhaling slowly is at that temperature. I am sure that the temperature

of the exhaled air would be slightly higher than the equilibrium temperature of our skin. After all, this air comes straight from the spots where fires of life are burning, using the oxygen in the breath intake.

On the other hand, when we blow out air through a small opening between compressed lips, we are subjecting it to another operation. First, we compress the air, increasing its pressure. Any increase in temperature is easily neutralised while passing through the passages inside the respiratory tract. When the air is expelled at a fast rate through the narrow opening between our lips, it expands. Like most gases, the expanding air cools. This is because energy is required to pull molecules away from each other. That is what Boyle's Law is all about. This explains your observation.

162. How do we smell things around us?

Smell is conveyed by transport of molecules of volatile substances to the receptors in our nose. The receptors are specific to the structure of different molecules, much like locks and keys. There are an enormous number of receptors, each sensitive to a different molecule. It is possible that different smells are often perceived through a coincidence in several receptors. The sense of smell is vital for many of the functions of living organisms. We can distinguish so many different shades. A baby can recognise its mother through the way she smells. We are protected from harmful things by their smell. Fragrances evoke memories. The taste of food also depends on the way it smells. Taste buds and smell receptors seem to work in concert. In the animal world, smell is even more central to functioning. We all know the capability of dogs to detect and follow specific smells. They can find hidden things, including narcotics in the bags of smugglers, or explosives hidden in boxes. Snakes track a field mouse using their forked tongues to detect the gradient of concentration in the molecules released from its body.

The science of smell is being extensively researched, with regard to the specificity of nasal receptors and the neural processing involved. Smell recognition also implies a delicate storage mechanism (or memory response) for the sensations that smells produce.

163. How do ants figure out where they have to go after they have collected food?

When ants move around, they can mark their path with an odorous substance - something that other ants (and they themselves) can smell. That is the reason why, on a food-acquiring mission, they travel purposefully along the trail laid by their leader. That is also the way they find their way home. If someone gets lost, a random walk brings it across a trail and a way home. I am sure many other complex messages are exchanged as well, enabling the intense degree of cooperatively we observe in their behaviour. If you see a line of ants going some place, you can try to see the effect of wiping out their trail with detergent. It would be quite a while before the train begins to move again.

164. What will happen to astronauts if they approach a black hole in a spacecraft?

Forgetting about all other effects, they will be stretched into invisibly thin strings! This would be caused by the large differential in the gravitational force between their toes

and their head. In other words, they would be subjected to unbearable tidal forces and be torn into pieces. This would happen much before they are anywhere near the black hole. You perhaps remember those beautiful photographs of the comet that hit Jupiter a few years ago; much before impact, the comet was broken into several cometary bullets by the tidal forces of Jupiter itself before it got hit in several places; the tidal gravitational forces exerted by a black hole would be incalculably higher.

165. What do scientists learn by "banding" birds?

There is a great deal of interest in learning about the migration pattern of birds. As you know, some birds travel thousands of kilometres each year, seeking breeding grounds suitable for raising their young, and then travel back home. Banding enables subsequent recognition of individual birds; if you could identify the place where the bird came from and when it left, you would learn a great deal. If you band a large number of individuals, you can also find their varying preferences, as also the dangers and hazards they have to overcome on various routes and distances.

These days, one can also put bands containing tiny transmitters and track the birds via satellite as they proceed on their journey.

166. I recall reading, in Einstein's unpublished work, about a concept called "ethereal rays". The work is supposed to be a scientific interpretation of things like mind travel (exemplified by Sanjay in the epic *Mahabharata,* who visualised the war from afar) and telepathy. Can any of this be true?

I do not believe any of this is true. I personally consider the Sanjay story of *Mahabharata* nothing more than a marvellous product of human imagination. It is true that when we have great empathy with someone, our thought processes might run along parallel or analogous lines even when we are physically separated from them. We could easily mistake this for telepathy. There is enormous amount of imaginative writing on these things, some clever, some downright silly. I am not an expert reference on these issues. Please do not implicate good old Albert Einstein in any of this.

167. Can the capacity of the brain be increased in any way? Or is it pre-decided, depending upon the gene pool that one comes from?

It is true that there might be some differences in intelligence between different individuals. Some of these differences may be genetic and some due to malnutrition during early childhood or a deficient upbringing. There is no strong evidence to show that these differences are racial or depend on the gene pool. Much depends on the social and intellectual environment children are exposed to.

The capacity of the brain can be increased if it is used more often. I have a feeling that the habit of accepting a lot of things on faith, without inquiry, can produce a mindset in which many processing capabilities of the brain first go to sleep and then are eliminated. The brain grows through use. Remember that honest intellectual inquiry and the spirit of questioning (rather than simply learning by rote) are vital exercises for a brain. While the memory bank is necessary, it is not productive without a high capacity 'processor'. The

programs and subroutines for the 'processor' are self-developed and cannot be bought from Intel or Microsoft.

168. Can earthquakes be predicted?

If you look back in time, you would realise that significant progress has been made in the area of geology and geophysics. We have identified areas on the Earth that are earthquake-prone, and can say with some certainty that they will be struck by an earthquake during the next few decades. I know that this is not enough. What we want to know is the exact place where an earthquake of damaging intensity would occur and the exact moment it would happen. This looks like a difficult task at the moment. But the situation is not entirely hopeless; several indicators are beginning to emerge, including those connected with the behaviour of animals just before an earthquake; these creatures respond to some precursor signals that we do not yet sense, or understand sufficiently well. However, in view of the advances in Earth sciences, I can foresee that the capabilities of earthquake prediction would advance significantly during the next few decades, even though we may never achieve perfection. In this regard we have to remember, for instance, that while we can now measure so many more parameters about the atmosphere and the oceans, we still cannot predict with sufficient accuracy, the occurrence of tornadoes and cyclones. The large numbers of interacting variables that impact these phenomena result in an astonishing degree of complexity. The best strategy is not to wait for extremely accurate predictions, but to design our habitats in a manner such that they do not collapse when the Earth decides to shake.

169. Why is a rainbow semicircular?

A rainbow is produced when sunlight suffers refraction while entering water droplets followed by total internal reflection at their back surface, and a second refraction while emerging from the droplets. Most of the light of the rainbow emerges close to the "angle of minimum deviation". This angle is 42 degrees with respect to the direction of incidence of sunlight. Therefore, we will see a rainbow at this angle with respect to a line connecting the Sun with the back of our head. This can be true only for a circular arc at an angle of 42 degrees. This circle intersects the Earth and, standing on the Earth, the largest sized arc we can see is a semicircle; this occurs when the Sun is close to the horizon. If however, we were up in an airplane, with the Sun directly overhead and raindrops hanging below us, we would be able to see a rainbow that is fully circular.

One can give a more general argument that does not require any detailed physics. In the phenomenon of the rainbow, there is only one preferred direction, namely that of the Sun. After it rains, water droplets are everywhere. Should there be anything like a patch of coloured light coming in our direction; it can be only democratically distributed, equidistant in angle with respect to the only special direction. Hence, the locus must be circular!

170. What do you think would be the consequences of such extreme emphasis on software development in India, and an absolute neglect of fundamental research?

Software development is a laudable pursuit. The purpose of developing any software is to use it (along with hardware) to achieve an objective. Much software is designed to make hardware more potent, useful and productive. The productive purposes are primarily determined by those who are in the driving seat. Most such entities are users, producers or peddlers of hardware. Therefore, I am convinced that ascendance of software alone cannot be a permanent feature in any self-respecting economy. We also find that there is a great temptation for pushing our bright people into the labour market of low-grade software because our people can work for less money than those of the industrialised countries. In addition, a lot of our young people are being engaged in information technology enabled services (call centres and the like), mostly for people in advanced countries. I suppose this is all right for the purpose of giving clerical jobs to some of our young people, but this should certainly not be categorised as knowledge work.

Yes, we should be developing software, but more and more of it should be "high-end". It should be for doing new things, designing new systems and creating new technology, including technology that would be most needed by our own country. And we should not make even such high-grade activity an excuse for neglecting hardware design and manufacture. I am disturbed that of late, the manufacturing industry in India has been on the decline. There's hardly anything that we have designed ourselves that is manufactured and marketed worldwide. Things that have been designed have not been picked up by our industry, which has got into the habit of riding on foreign brand names.

One aspect of the present attitude worries me even more, since I believe we are in danger of mortgaging our future. If all our bright students move away from science and engineering research, attracted by the lure of so-called software, or a job in sales, finance or general management with a foreign or hyphenated Indian-Foreign company, there would not be an Indian identity left in tomorrow's world. Some might think that is a desirable direction to pursue. On my part, I would begin to question the need and relevance of the century-long enterprise that was our freedom struggle.

171. Can genetic manipulation make a person more intelligent?

Perhaps, sometime in the distant future. The tools of modern biotechnology will first be applied in trying to correct genetic defects. Some children have a problem concentrating - their attention span is low. I do not know whether intervention would be possible in such cases. Personally, I would be very suspicious of programmes that interfere with natural development of the human mind in any way. In view of the way we are presently motivated, any success in manipulating people's brains (beyond the brainwashing we are already engaged in), would probably be more often used to produce morons who will consume more, kill their fellowmen more efficiently, or who will not mind being perennial servants. The best future for the world lies in freeing brains and minds, and in naturally evolving, multi-spectral development. I am sure there would be many who would not agree with me; I am sure Hitler would have jumped at the possibility of creating a master race. I do not think there is any possibility of our going in that direction, which is fortunate.

172. It is said that sound waves cannot travel in a perfectly rigid body. Then why is it that the velocity of sound is quite high in iron, which is considered one of the most rigid bodies?

Nothing is "perfectly" rigid. Perfect rigidity would imply that neighbouring particles are held together with infinite force. Iron is not that rigid. Nor is anything else, not even a neutron star.

173. Can anything travel faster than the speed of light?

I do not know of any "thing" that has mass or energy that can travel faster than the speed of light in vacuum. You can make equations in which particles of imaginary mass might travel faster than the speed of light. I do not know of any such particles. Yes, there is something that can move at any speed, and that is human imagination. But remember. That is not a "thing". It has no mass, energy or momentum.

174. When I sit on a merry-go-round and then get off, why do I continue to experience the sensation of circular motion?

You have asked a simple question that hides some beautiful complexity. We seldom wonder about the marvellous mechanisms and methods that keep us functioning. The question you have asked is intimately connected to the mechanism that provides us a sense of balance. Let me see if I can put across some understanding of the equipment that provides us this capability without using specialised anatomical jargon. I will also avoid detail, partly because I am myself not so well educated in this area.

Inside both our ears, there are three semicircular canals, oriented in three mutually perpendicular planes. These canals happen to be positioned at that location, but have little connection with the function of hearing itself. This location seems to have been chosen for its convenience - on two sides of the head and close enough to the communication lines of the central nervous system and the spinal routes that provide reflex action. Reducing this balancing system to a simple physical analogue, we could describe it in the following way: The mutually perpendicular semicircular tubes are filled with a slightly viscous liquid. On the walls of the tube are a large number of tiny hairs whose bending would alter a signal going to the nervous system, which controls the position of the head, pointing of the eyes etc. Let the tubes also contain a ball, or something with inertia that can move in the viscous fluid. Now rotate the head, say in a horizontal plane. The ball in the horizontal tubes would lag behind and would appear to move in a direction opposite to that of the head, or the canal. This would stimulate the hair by bending them backwards. Your sense of being on a merry-go-round would be derived from the signals originating from there. When the merry-go-round stops, the ball will keep going for a while - because of inertia - sending signals in the opposite direction, giving you a giddy feeling and upsetting your sense of balance. Remember that you have these tubes in three perpendicular directions. This would make you sensitive to disturbances in all the directions. With this simplified description, it should be possible to understand the experience of the kind you have mentioned or others, such as motion sickness or disorientation of astronauts during and after space flight. Apparently, the reason that

some people (like me) suffer from vertigo is also due to the fact that the semicircular tube apparatus is partially faulty.

From a physical point of view, the basic elements seem to be the following— 1. Three semicircular tubes, oriented In mutually perpendicular directions to cover all kinds of head movement. 2. Two sets of these tubes, one on each side of the head, close to the inner ear. 3. Some fluid in the tubes and a large number of fine hair sticking in, whose disturbance produces or modulates signals, and 4. A ball-like object, heavier than the liquid in which it is suspended, to provide relative motion with respect to the tube during acceleration and deceleration. The rest is just signal processing and moving apparatus like muscles and pivoted bone levers.

The whole of this marvellous system is known as the "vestibular" system.

{I would .like to warn that if any of you medical students were to answer a question on this topic in the manner, and with the language I have used above, you are likely to flunk. This is only an attempt to share a bit of the joy of understanding, not necessarily to pass a normal examination).

175. What is the use of the glass sheet in a solar cooker?

To raise the temperature within, a solar cooker has to allow the maximum possible energy from sunlight to come in and lose the least amount through re-radiation to the environment. Most of the Sun's energy is concentrated in the visible range of radiation. A glass sheet is transparent in this range, so it allows a large fraction of the Sun's energy to enter the cooker. The temperature inside the cooker may rise to 100 degrees Celsius, at the most. At this temperature, most of the radiation is in the infrared range; in other words, it is heat radiation. Glass is not very transparent at these wavelengths. This radiation is trapped inside the cooker, thus raising the temperature. Of course, ultimately, the energy going out must become equal to the energy coming in. This balance is achieved only after the cooker temperature has been elevated. But this is all we want from the cooker - that the temperature inside should rise in order to cook the food. In a solar cooker, the glass sheet plays a role very similar to that of carbon dioxide in the atmosphere. Carbon dioxide allows sunlight to reach the Earth, but it absorbs a significant fraction of the heat radiation going back into space till the temperature rises to a range compatible for life. The solar-cooker type of physics also comes Into play in heating a stationary car that has been sitting in the summer Sun with its windows rolled up, an experience no motorist in India can forget.

There is one point that is not properly understood by many people. The role of the glass sheet or the carbon dioxide is to raise the temperature of the cooker, or the Earth, to a level such that the outgoing energy is the same as the incoming energy. The amount of the incoming energy is not changed. The glass sheet and the carbon dioxide both act as blankets.

Speaking of another kind of blanket, we cover ourselves with a woollen variety during winter nights. We should understand that in that case, the source of energy is inside the blanket - the heat generated through body metabolism. We adjust the quality and thickness of the blanket to ensure that our temperature remains in a comfortable range.

There is a lot of physics involved in living. But even babies learn it quickly, almost automatically.

176. Why does hair colour change to white as we become old? Is there a way to stop this?

Hair itself is a string of dead cells. Hair follicles on the skin are alive, however; the colour of hair is due to the melanin manufactured by the skin cells. Your question then becomes "why do the skin cells near the hair follicles stop manufacturing melanin when people grow old". One might as well ask "why do people grow old"? I think this is built into the programme of all living things. Some organs and systems function less efficiently as we age. Many of us need spectacles to see properly after the age of 45 years. Our teeth fall off. The skin becomes lose and wrinkled. We develop arthritis. Our bones become weak. We cannot run as fast. Wounds take somewhat longer to heal, etc; the list goes on. We all know that growing old is a period of physical descent. It may not be uniform for all of us. There might be individual differences in the rate of decline, depending on genetics or lifestyle. A lot may be known in this regard, but there is still much to discover.

177. It is said that every star has a solar system. Doesn't it follow that it would have orbiting planets as well?

We do not know whether every star has planets around it. But it is likely that a large fraction of them do. In some sense, you might say that it is difficult to make a star without making any planets around it. This does not mean that those planets would be like the Earth. They might be too close to the star or too far. They might be very massive, like the Jupiter or Saturn, and evolve very differently. At a certain point in its history, a large population of asteroids might even dominate the stellar family. It is unreasonable to assume that the primary concern of every star should be to gather, or help generate, planets that would support life like that on the Earth. And yet, there might be a very large number where conditions like those on the Earth occur. Incidentally, when you use the phrase "Solar System", it usually implies that the star has planets around it.

178. Why do antibiotics not affect virus?

An antibiotic is an agent that interferes with the development machinery of an undesirable biological invader. On the other hand, a virus does not have its own machinery. It is pure genetic information that takes hold of the metabolic apparatus of the host. In the process, it also replicates itself. Since a virus does not need to eat or grow, it can lie dormant and survive for long periods under very adverse conditions. It has been suggested that viruses could also survive the vacuum of space! Viruses are like fundamentalist rhetoric. The only way to avoid damage is to keep it away from "hosts" that would make it bloom. If the virus is forced to lie dormant for a long time, it can perhaps wither away. The thought occurs that lot of mutual understanding might emerge from a collaboration of computer scientists (who deal with the menace of software viruses), medical scientists and social engineers.

Conventional antibiotics were isolated from fungi, on the basis of the observation that they could inhibit the growth of bacteria. The term has therefore come to be associated with anti-bacterial activity. Compounds that have potent anti-viral effects have been developed (for example AZT and protease inhibitors) that prevent the growth of the HIV virus and have prolonged the lives of many patients. Many labs are also investigating the effects of extracts from plants such as neem for anti-viral activity.

179. What is meant by the spin of a subatomic particle?

Fundamental particles behave as if they have definite, quantised values of intrinsic angular momentum. This is usually referred to as spin. Even nuclei have spin. In systems of more than one particle, such as atoms, there also exists another kind of angular momentum, called orbital angular momentum. The energy levels of systems are influenced by the interaction of angular momenta in a known, calculable manner. Conservation of angular momentum influences the outcome of interaction between particles. It seems truly amazing that in terms of quantum mechanics, one can almost imagine electrons spinning like tops. Charged spinning particles also produce magnetic moments, which also contribute to the energetics of atoms and nuclei. In the every day world of a citizen, Magnetic Resonance Imaging is an oft-repeated phrase; the resonance is between the energy levels of atoms and molecules and the external magnetic field.

It turns out that the spin of fundamental particles is a property that has a deeper significance, in the sense that it divides their world into two distinct families. Particles with half-integral spins, such as the protons and electrons etc. are called Fermions and are subject to Pauli's Exclusion Principle. This has had a fundamental bearing on the real world of atoms and their structure and properties, including, of course, chemistry and biology. Bosons, with integral spin, are outside the regime of this Principle and their statistics are equally, though differently, central determinates of the world as it is.

180. Isn't it possible that atoms don't exist? As far as I know, they have never been directly observed, and their existence is based only upon experimental observations. Is it possible that, instead of atoms, only pure energy exists, and chemical reactions occur as pure energy transformations?

You never see atoms or particles with the naked eye. You only learn about them through experiments. All chemical reactions are determined by the properties of atoms. In order to understand the natural world, you must use the properties of atoms and molecules as determined by a great variety of experiments. No my friend, it would be a grave error to dispute the existence of atoms (and indeed, of sub-atomic particles), given the weight of accumulated evidence. They are centrally involved in determining how your so-called "pure energy" would behave. Please reserve your skepticism for other, less certain and more speculative ideas.

181. Why do light bulbs immediately begin to glow as the current is turned on, and tube lights require a few seconds?

The filament in the light bulb is made of a high resistance wire. The heat capacity of this wire is low. Therefore, it is quickly raised to a temperature high enough to balance the energy emitted as light and heat and that produced through Ohmic loss by the current flowing through the filament. That is why the light bulb begins to glow quickly.

When you switch on a tube light, the current cannot pass unless a plasma discharge is initiated by delivering a high voltage pulse. You would remember that the starters of ordinary tube lights contain ballast and a condenser. The ballast is essentially a high impedance choke. The condenser reduces the electromagnetic interference. The heating of the electrodes at both ends of the tube leads to emission of electrons, which are the initial carriers of the current for the discharge. The current for heating the electrodes is cut off after the discharge begins, because the electrode temperature is then kept high by the impinging ions. The high voltage to initiate the discharge is produced by interrupting the current in the ballast. The initial heating of the electrodes takes a little time. This is the reason why ordinary tube lights require a few moments before they begin emitting light.

182. Is it true that exposure to ultrasonic frequencies can make seeds germinate faster?

My answer is that I do not know the answer. I have scanned the Net and could not find anything definitive. If you come across some reliable information in this regard, I would like to hear about it. One will have to define the strength and frequency of the ultrasound. If the signal is too strong, one could smash the seed. Germination is a biochemical process, and I do not know how such processes could be speeded up by ultrasonic bombardment. But as I said earlier, I really do not know the answer.

183. Is there such a thing as anti-gravity?

My first answer to this would be in the negative. Anti-gravity is science fiction. However, I must be a little cautious, because some descriptions of the very early evolution of the Universe suggest that it might have inflated very fast for a tiny instant soon after its creation (or the “Big Bang”). But to think of this as being due to anti-gravity might be premature or simplistic. Outside of this, I do not think it would be possible to invent an anti-gravity machine!

184. Can machines ever become as intelligent as humans?

This issue has sparked an active debate amongst the artificial intelligence community. Some of the earlier enthusiasm has waned. It has been shown that computers can play chess as well as the best players. But is being good at chess a comprehensive definition of intelligence? Detractors argue that it is not possible to find a representation for all human experience and observation. That which cannot be so represented in a format that a computer can process will therefore be excluded. Others counter that this cannot be interpreted as saying that such representations are impossible. If everything from love to hate, affection to aversion, patriotism to linguistic jingoism, and reverence to friendship could find representation, then a powerful machine could do things that would be difficult

for an ordinary intelligent human. I have a feeling that for the moment, the argument is settling in the following direction — we have already shown that there are things that machines can do more efficiently than humans. This includes taking quick (but not necessarily correct!) decisions and acting on them. The contribution of computers towards increasingly diverse areas of human endeavour has been invaluable. The geography of the region where this can happen is likely to widen. It would be a mistake, however, to expect that computers (or other machines) might, or should, begin to mimic human beings. The beauty of human intelligence, imagination and individuality might never be realised. The same would be true of humour, poetry and compassion.

185. Why are some objects transparent and others opaque?

Normally, when we talk of objects being transparent or opaque, we describe whether or not visible light can pass through them without too much attenuation. What is transparent in that narrow band of frequencies we call the visible region of the spectrum might be opaque at other frequencies. For example, our atmosphere is transparent to visible light and radio waves but it is opaque at a rather large band of wavelengths in the infrared region, and to ultra violet, x-rays and gamma rays. Transparency depends on the fact that the medium has no energy levels that could be excited by the photons of the light in question. An interesting case much in the news today is that of ozone. Ozone consists of molecules made of three atoms of oxygen. The ozone molecule has just the right energy levels to absorb lower ultraviolet radiation, and therefore protects us from its harmful effects. A small amount of ozone in the upper atmosphere can do what a large amount of air below cannot. The same ultraviolet cannot find an energy level in nitrogen or oxygen in the air that would resonantly absorb it and stop it from reaching ground level. This is the reason we are so worried about ozone depletion.

Take another example. Long wave radio works because the ionosphere does not allow such waves to escape into space, but reflects them back. Short wave or television signals pass through the ionosphere almost unhindered. Therefore, we need satellites high up in space to retransmit these signals back to Earth to provide global television and short wave radio.

Transparency will result if there are few energy levels in the medium that can help in absorbing the signal. This is true of glass in the optical region of the spectrum. The same glass is not so transparent in the infrared. That is why in summer, a car sitting out in the Sun with the windows up becomes so hot inside. When you come back after some shopping and open the door of the car, it feels like an oven. The heat radiation inside has a hard time getting out through the glass widows and windshields. Global warming, resulting from increasing concentration of carbon dioxide, occurs due to a similar effect.

186. Why did the Mir space station fall to Earth?

Mir did not fall to the Earth unassisted. It was de-orbited, which is to say that its orbital velocity was changed by the firing of rockets. A lower centrifugal force led to the descent of the space station. As the density of the atmosphere increased, so did the frictional force. The descent became faster, frictional forces tore the station apart and much of it disintegrated and burnt up like a meteor in the heat that was generated. The

larger pieces that survived atmospheric entry fell into the ocean. To a large extent, it was a controlled descent (though nowhere as well controlled and gentle as the landing of the space shuttle, but controlled nevertheless) because it was necessary to avoid populated areas of the Earth from a shower of debris from the skies.

Hidden in your question, I think, is another one. Why did it become necessary to bring down a space station that had been going around the Earth for so many years? A space station needs continuous maintenance. Not being at very high altitude (less than three hundred kilometres, perhaps), it was subject to frictional deceleration by the small amount of air still present at that height. There were also the perturbations caused by the pressure of the solar wind on its body and the solar panels. It needed to continuously change orientation to meet the requirements of various scientific functions. For the sustenance of the astronauts, Mir had to be serviced by a continuous stream of supply ships; it was a small habitation, most of whose requirements had to be met through transportation from the Earth. The control systems and computers had become dated and needed repairs and maintenance.

The Russians felt they could not afford to go on maintaining this station and simultaneously meet their commitments for the International Space Station being set up in collaboration with the Americans, the Europeans and the Japanese. That is why the Mir station had to be laid to rest. It could not be left there because it would have eventually come down in any case if left unattended. To allow that would have been dangerous and irresponsible.

187. The other day, I started to casually rub the rim of a glass with my wet finger; after a while, a humming sound emanated as a result. Why did this happen?

That was a good observation. If you had done that using a wine glass with a long stem, the sound would have been purer in pitch and louder. I would like you to do some experimentation. Put different amounts of water in the glass and try to observe if the pitch of the sound changes. You will find that it does. The glass has a natural frequency of vibration, depending on the length of the air column, besides its structure. Strike the glass with a spoon and listen to the pitch of the sound. Then, do your moving-a-wet-finger-over-the-rim experiment. You should find that the dominant pitch is the same. This shows that the finger is not creating any special magic. It is continuously exciting vibrations in the glass because of the friction between the slightly wet finger and the rim of the glass. It is because of the continuous stimulation by the finger that you get a continuing sound - you will find that an excessively wet finger is not very efficient in this regard because the friction is reduced or eliminated. In fact, this is rather similar to the way a bow excites vibrations in a violin string. The sound is almost continuous but at the same frequency that you would hear if you plucked that string.

All things are, in principle, musical instruments, some better than others. In many of them, cavities of air, their shape and length, are crucial. Remember the instrument called the ‘Jal-tarang’? If a bow could be drawn over the rims of the cups used in the ‘Jal-tarang’, we would have an entirely different musical instrument! If you play the violin or have an access to a bow, you might find that the bow could perhaps replace your wet finger.

188. When a few drops of water drop into hot oil, what makes it crackle and fizz?

Hot oil is very much hotter than the boiling point of water. When you put drops of water in hot oil, they sink in a little (water being heavier than oil) and then convert into steam that escapes with explosive force. That is the reason for the noise. Of course nothing like this happens if you pour a little oil on boiling water, for the obvious reason that oil stays near the surface and cannot be vaporised suddenly because the boiling water is just not hot enough.

189. How do fish get the oxygen they need from water?

Some oxygen is always dissolved in water. Fish extract it by using their gills. You must have noticed that in a home aquarium, a motor keeps blowing air into the fish tank; you can see the bubbles rising up. This is to oxygenate the water and keep it "breathable" - that is, for creatures with gills.

190. Why does the Sun look bigger when it is low on the horizon than when it Is overhead?

This observation applies equally to the Moon; the Moon also looks much bigger when close to the horizon than when It is high in the sky. The consensus is that this universal experience has nothing to do with the physics of seeing or the size or shape of the image. You can easily check that the actual size of the image is the same, independent of the location in the sky. This is very conveniently done for the full Moon using nothing more than a transparent scale held at arm's length with one eye closed. No doubt, you will convince yourself that the actual size of the Moon does not change as the Moon climbs up in the sky (A NOTE OF CAUTION: IT IS HAZARDOUS FOR THE EYES TO TRY THIS WITH THE SUN, UNLESS YOU USE A CERTIFIED FILTER!!!). In any case, you can take it from me that physics is not fooled by the proximity of the Sun (or the Moon) to the horizon. But we are. This optical illusion is fundamentally linked with the way our brain interprets images. It uses past experience - some facts, and some prejudices - to give meaning to the visual signals received in the cortex. We are aware of a large number of optical illusions. But the field of psychology is not as certain, or crisp, as mathematics. Two possible explanations have been put forth for this observation; see if they satisfy you.

When the Sun, or the Moon, is near the horizon, we see it in the company of other distant objects - buildings, trees, and hills - objects whose sizes our brain is familiar with. These distant objects produce a small image, but the brain, from past experience, applies a process of mental amplification, which justifies and rationalises the sizes of these known objects. The error occurs when the brain applies a similar amplification strategy to size up the "adjacent" Sun or Moon!

Another explanation goes like so:

When we stand out in the open, very far from anything else, we get an impression that the sky is an inverted bowl. This has been felt and believed for thousands of years. We do not know the height of this bowl, but get a feeling that it cannot be as much as the

distance to the horizon. After all, we know that the horizon, where the rim of the bowl seems to meet the ground, must be very far because known objects look so small at that distance. So it seems natural for the intelligent interpreter sitting in our brains to make the Sun and the Moon appearing near the horizon look bigger than they are! When high up in the sky, the brain feels that these objects cannot be as far as the horizon since the bowl is believed to be rather shallow! So the interpreter applies no correction! I can appreciate the qualitative directions of this explanation, as also the previous one, but the quantitative angle escapes me. Why does the Moon appear just this much bigger near the horizon, and no more? Do we even know if it appears to be the same size to different people? Maybe some people's brains "amplify" it more than others (eg. adults v/s infants?). Since the effect is illusionary (and therefore not physically demonstrable), could we even measure this difference in perception? Perhaps someone knows the answer - or maybe some day in the future we will!

191. I have heard that plants grow better when soothing music is played. Is it true? If so, how is it possible?

I have also heard this. Indeed, I have heard even more. It has been said that cows give more milk when slow, melodious music is played, but not so when the music is loud and fast - the kind many young persons seem to prefer these days. Apparently cows are seeking tranquillity, not excitement!! Whether any of this is also true for plants, I do not know. It is quite possible that only those persons would play music to plants that are in love with them and, therefore, look after them rather well. The flourishing of plants might as well be ascribed to good nourishment and not to a musical environment. But seriously speaking, I do not think there is definite proof for or against this conjecture.

192. Is it true that body weight increases after death?

I am not aware of this. A dead body feels heavier to carry, much like a person who is unconscious or drunk. The perception is probably due to the fact that a dead person does not cooperate in distributing his weight on to different parts of your body - for example, by putting an arm around your shoulder or clasping his legs around your middle. After a while, the remains of a dead body must weigh much less because much of the body degrades through the action of bacteria.

193. When travelling in a train, the occupants move along at the speed of the train. Consider a fly in one of the compartments; does it have to fly faster than the speed of the train or is the train stationary for the fly?

Why only talk of a fly? What about you, walking through the corridor of a train running at a hundred kilometres per hour? Surely, you walk as you would on ground, say at 6 kilometres an hour (except for the jerks). To an outside observer, you would be seen to be moving at 106 or 94 kilometres per hour depending on which way you are walking, relative to the movement of the train. In a smoothly moving train, you spend the same effort walking as you would on ground. But why ride a train to prove this fact; the Earth is also moving at great speed. We do not have to run to keep up. We are not even aware of a difference in the effort required to run in different directions on the Earth. If you fly

in a modern jet liner at 900 kilometres per hour, you are not even aware which way you are going. If the plane were big enough, you could play table tennis or football using the same skills and dexterity you have acquired while playing on the ground. And a fly travelling with you in the plane uses skills learnt in Delhi, London or New York for landing on a piece of cake. Our locomotion, as of the fly, is with respect to the frame of reference in which we are located.

So the fly does not have to fly any differently in a moving train - provided, of course, it is not next to an open window where a blast of air might blow it away!

194. Why does a dead body float to the surface after 24 hours in the water?

A dead body usually floats with its head submerged in water. But, that even a live person can do. However, a live person needs to keep the heaviest part of the anatomy, namely the head, out of water, at least for sometime, in order to breathe. A dead body has no such requirement. The body would start to decay soon after death. The decay process releases some gaseous by-products. We all know that cadavers release unpleasant odours. It is possible some of these gases make the body bloat and hence become lighter than water. This is perhaps the reason it floats to the surface.

195. Whenever force is applied, energy is spent. It follows that the Earth should be constantly losing its energy as it is applying the force of gravity on all of us. Does the fact that this does not happen defy the laws of mass and energy conservation?

I think your arguments are faulty. Let me explain. Energy is expended when a Force moves something through a distance. You perhaps remember that Force is equal to Mass multiplied by Acceleration. When you lie on your bed, every particle in you is in mutual attraction with every particle in the Universe, including those in the Earth. Unless this attraction leads to some movement, some bending or change, there is no energy being gained or lost. If you jump off a roof, your gravitational energy is converted into kinetic energy that can be used for movement of the air you push out of the way on your way down, for breaking one of your bones, for generating some heat on the ground you hit and for making a hole in the Earth. But this energy stays constant and unused if you just keep lying on the roof. When you walk up the stairs to the roof, you use your food energy to increase the gravitational energy of the you - Earth system. This becomes available when you jump off the roof. When a large cloud of gas and dust collapses due to gravitational attraction, the potential energy of gravitation is converted into heat and, after the start of thermonuclear reactions, you get a star.

196. What is the difference between frozen snow and ice?

Frozen snow is a large number of tiny ice crystals piled up together with a lot of air spaces in between. It looks so white precisely because of this structure, in which there are an infinite number of ice-air interfaces to scatter the incident light. Indeed, there is so much entrapped air that people buried under snow can actually survive for quite a while if they use some porous covering on their faces. Ice is highly compacted frozen water from which all air pockets have been removed. This happens under pressure. For

example, the thick mass of ice, some kilometres deep, on Antarctica is quite transparent. The water constituting this ice must have precipitated as snow, some of it thousands or millions of years ago.

There is also, of course, the ice we make in the freezer compartment of our refrigerator. That is also transparent. Clearly, the conditions in our freezer are not designed to make snow, though you must have noticed that freezing of moisture on the walls of old freezers results in the formation of a whitish cold mess that is not clear like the ice in the ice tray. It is more like hard snow than honest ice.

197. The Earth attracts the Moon, and attracts objects such as meteors. Why is it then that meteors crash into the Earth while the Moon does not? How does the Moon stay in perpetual orbit despite the Earth's attraction?

Let me take the last part of your question first. Everything that has mass, or energy, is subject to the force of gravitation. Every particle in the Universe attracts every other particle. The force is proportional to the product of their masses and inversely proportional to the square of the distance between them. When you simply drop a ball from the top of a building, it drops straight down to the ground. If you throw it outward with some force, it still drops to the ground, but only after going some distance in the horizontal direction. Imagine now that you are Superman and the Earth has no atmosphere (and so, offers no friction). You could then throw the ball horizontally with such high speed that, even though it keeps falling towards the Earth; it never actually hits it. It could keep going round and round and become a satellite, much like the Moon. If you had not imparted such horizontal velocity to it, it would fall on to Earth.

Now take the case of a meteorite. Meteorites are primarily residents of the asteroid belt between the orbits of Mars and Jupiter. In this belt, many objects, big and small, keep going around the Sun, much like the Earth and other planets. But these asteroids also have random motions, which get affected by interaction with each other as well as by the force of the planets near which they might happen to pass. Some times these stones are perturbed into orbits that might pass close to the Earth. Most of the time they just pass by but sometimes, gravitational attraction may pull them into a collision course. Thus, meteorites do not fall to the Earth only due to the mutual force of attraction but also due to opportune velocity and direction.

198. What is the "diamond ring" observed during a solar eclipse? Is it normally present? Is it a part of the Sun or the Moon?

During a total solar eclipse, the Moon completely covers the Sun. Now think of the moment when the Sun begins to emerge from behind the Moon. The Sun is round and so is the Moon, but not perfectly so. The Moon has ridges and valleys. There always will be one valley in the line of sight that is deeper than the others. It is natural; therefore, that the Sun will shine through that lunar indentation before it emerges out of the lunar edge, suddenly appearing like a bright diamond in the middle of a thin streak of light along the lunar edge. Such a "diamond ring" can be seen either just before, or just after total eclipses. Adjacent to the spectacle of the diamond ring, we sometimes also see a number of bright "beads". This latter spectacle would occur when there happen to be several

valleys or depressions, approximately in the same direction, roughly pointing towards us. These bright spots are usually referred to as Bailey's Beads. It should be clear that these beads, as also the diamond ring, might not appear equally spectacular in all eclipse events.

199. Why are jet engines normally located below the wings of an airplane? Does this positioning offer any structural advantages?

There are airplanes in which a third engine is mounted high up, near the tail of the airplane. As far as the wing-mounted engines are concerned, however, your observation seems valid. I do not really know the answer but let me hazard a guess. I believe it would be sensible to have the thrust vector of the engines lie in a plane that is close to the centre of mass of the airplane, because this would avoid torques, or rotational forces. This requirement would rule out a top-wing mounting. Another (perhaps more basic) reason could be aerodynamic. The upward thrust supporting the airplane results from the fact that, due to the shape of the wings, the velocity of air moving over the wings is higher than of air moving under them. Were engines mounted above the wings, the air movement there would become turbulent, thus increasing the pressure above the wing and, therefore, reducing the lift. I would welcome a better explanation from an expert.

200. We know that mass can be converted into energy through nuclear reactions. Since energy can neither be produced nor be destroyed, the amount of energy in the Universe is constant. But nuclear reactions add to the amount of energy. This means it is not true that the amount of energy is constant but rather that the amount of energy + mass remains unchanged in the Universe. Is this true? If mass can be converted into energy, it might be possible that energy can be converted into mass by an unknown process. Our religious *Puranas* too say that at first there was energy, and mass came into existence later.

Your long question can be answered rather simply. Since mass and energy are just different forms of the same thing, the back and forth conversion depends only on conservation laws - other than laws governing the conservation of energy and momentum. Remember that energy also resides in fields, including the gravitational field. The processes through which energy is converted into mass and vice-a-versa are fairly well known. I must say I do not believe that the *Puranas* or any other old religious books have any impact on any of this. Often, the truths in these religious texts are 'discovered' after they become manifest through detailed secular endeavour.

201. When we touch a liquid, it sticks to (or wets) the skin, but when we touch a solid, why does this not occur? Also, why is water transparent and ice whitish?

I appreciate your curiosity. Let us look at your first question in a simple way. If something sticks to your fingers, it implies that its molecules are not so strongly held together to each other. Some of them can separate from their companions and go their own way. This they can do if there is something that attracts them. When you put your finger in water, some of it sticks to you because there is an attractive force between the material of your hand and the water molecules. Water does this with a wide variety of

materials. If you look at the surface of water in a test tube, or for that matter in a glass, you would notice that near the walls of the glass, water seems to rise a little; as if it wants to climb up. In fact, if the tube is narrow enough, as in a capillary tube, water will rise quite high. That is how oil rises in the wick of a lamp, or sap to the top of a tree. If water did not wet your hands, we would not have had any plants and trees! This would be true if the trees decided that they prefer to be made of Teflon, the material with which some modern non-stick frying pans are coated. It is worthwhile remembering that all liquids do not behave the same way. For example, mercury does not wet your hand, nor would it rise in a glass capillary tube. Such behaviour is determined by the nature of intermolecular forces.

Let us now come to the second part of your question. Why do solids not stick to your fingers? The simple answer to that is that solids are solids because their constituent molecules interact in strongly bound architectures. Molecules are not as free as they are in liquids. This is not strictly true, of course. If you were to rub your finger on a gold or silver plate, a sensitive instrument could detect the residue on your skin.

I just noticed that you have another question at the end of your query. Ice is not transparent because it usually has tiny air bubbles mixed and trapped inside. It is only compacted snow. Under pressure, air can be squeezed out. For example, if you took a core of ice from Antartica you will find it to be quite transparent. Good ice-makers also make transparent ice cubes. Try making Ice cubes in the freezer section of your refrigerator with water that has been recently boiled to drive out most of the air. I do not know if this experiment will make the ice more transparent; let me know the result of your experiment.

202. Why does our mouth water only when we see or think about pickle and not when we see any other food stuff?

You must be very fond of pickle. I do not know whether pickles are universally effective in inducing mouth-watering. My mouth waters when I see some fresh ‘amarti’ or laddoo’. Watering of the mouth is advance preparation for digesting what you are going to eat. Human saliva plays an important role in breaking down food into useful things our body can use. It is not just some watery liquid to soften the food.

203. It is a general belief that life is not possible without oxygen. But if the Universe contains planets very different from Earth, why cannot living beings that have evolved there utilise some other gas?

When we think of life, we usually have creatures like us in mind. We forget that even on Earth, there are anaerobic bacteria for which oxygen would be poison. Bacteria also represent life. We do not know what other forms of life might be possible. Viruses can “live” without oxygen and under extreme conditions, including high vacuum; they may be considered as copies of information that exploit other life forms to reproduce themselves. In that sense, they represent a parasitic form of life. No sensible exobiologist would insist that when we find life on any other planet, we would encounter beings with similar features and with physical, social or psychological characteristics identical to what we find on Earth.

And yet, we can be excused for suspecting that, given the universal abundance of elements and the universality of the laws of nature, a pathway to life somewhat analogous to that which developed on Earth is not too unlikely. Even then, the finer manifestations would be hard to predict, considering the enormous variety of life forms that have evolved even on our own planet. Except for planets in our immediate neighbourhood (to which we can send unmanned probes), we may be constrained to detecting only those extraterrestrial civilisations that have developed the technological capability to communicate with us.

204. If we make a hole all the way through the Earth and we drop a ball in, where will it go? Isn't gravity 'zero' at the centre of the Earth?

You are, of course, only doing a thought experiment. No one can make a clean hole through the Earth. As soon as you puncture the crust and dig a few kilometers, you would have created a volcano! But in our thought experiment, we should not be disturbed by this minor complication. Like you, I will assume that we do have a clean, evacuated and cool hole going right through the Earth. And now we drop a ball inside. The ball will fall in and accelerate due to the force of gravity. As it moves, acceleration will reduce but the speed will go on increasing till it reaches the centre. As you correctly point out, gravity at the centre, which is the same thing as acceleration, would be zero. So, for some moments, the ball will travel at constant speed. But soon it will experience an increasing decelerating force as the gravity increases on its journey away from the centre. The ball will slow down and become stationary as it reaches the other side of the hole and you would be able to catch it quite easily if you can rush there in time. However, do not fret if you fail to catch it. Just rush back to the other side of the hole and try again. You will have opportunity to try again and again because the ball will go on oscillating between the two ends, much like a pendulum.

205. Why is Earth's orbit elliptical?

You must have heard of Kepler's laws. These laws pre-dated Newton and were derived from observation, deep thought and extrapolation. Subsequently, Newton's laws of motion and gravitation provided corroboration by requiring that planetary orbits be elliptical. Of course, the ellipse becomes a circle if the major and minor axes are equal. Therefore, the Earth orbit, like all other planetary orbits is also elliptical, though the eccentricity is quite small.

206. Why do we lose count even at the slightest distraction?

I wish I could answer this question scientifically. This is one of those observations about which every one agrees. One can also propose reasons as to why it should be so, but it is difficult to really know for sure. Though a lot is known about the faculty of memory, precisely how it works is not quite understood - perhaps some people understand it, but I certainly do not. I can quite appreciate that evolution may have preferred that the mere process of counting should not consume too much of the resources of the brain - it should become an almost automatic activity. But in order to do that, the numbers must be put on some sort of a string so that one comes after the other.

The only instruction from the brain might be "after this jump to the next bead on the string, do not pay any heed to, or store, what you have already crossed". It is clear that when this sort of operation is going on, any diversion would move your attention from the "string" and you would not have any idea about the "bead" you were on. Usually, you would have to start all over again from the beginning. I have a feeling that some similar operation is in motion when we try to remember a song or its tune. Occasionally, we latch on to an intermediate point in the "string", some words or a phrase of music, and we can then go forwards or backwards.

207. Why does the speed of light appear constant irrespective of the speed of the source and the observer?

Electromagnetic theory states that in vacuum, all zero mass particles (photons, for instance) have to move with the velocity of light, no more and no less. This does not mean that light emanating from a moving source is unaffected; it shifts in wavelength due to the Doppler Effect. Movement between the source and observer does have an effect.

208. When I punch a wall and there is no visible effect upon it, does it mean the energy I expended is wasted or destroyed? Would this not go against the law of conservation of energy?

When you punch a stiff wall, you may bruise your hand or even break a bone. That requires energy. You might also cause an indentation on the wall; though the dent may be small, the energy required to cause it might have been significant. Some of the energy might also be consumed in agitating the molecules in the material of the wall, resulting in a slight rise in temperature. The Law of Conservation of Energy is never violated.

209. When Rutherford performed his alpha ray experiment, he shot helium nuclei through the atoms of a gold foil. Don't the alpha rays combine with the electrons in the atoms and thus destroy its stability?

Alpha rays are Helium nuclei. When they move through any material, such as gold, they encounter a sea of electrons. This encounter is due to the electrical force between the positively charged alpha particle and the electrons of the atoms of gold. This interaction results in ionisation of the atoms, in which the alpha particle goes on losing some energy. But the velocity of the alpha particles is such that the probability of capturing one or two electrons from the environment is very small till they slow down and become atoms of Helium. During its passage, the alpha particle does destroy many atoms through ionisation, but they capture the lost electrons from the environment and become whole again. It is clear that in this process, some radiation is also created. Quite a lot of on-going drama.

Rutherford found that sometimes the alpha particle was deflected through a large angle, which would require collision with a concentrated mass. That lead to a momentous discovery - an atom has a heavy core we call the nucleus.

210. Can light be affected by gravity? If so, how does this occur, since photons have no mass?

Yes, light is affected by gravity. This is a central element of Einstein's General Theory of Relativity. One way of looking at this was to say that the presence of mass curves the space around such that the shortest distance between two points is not a straight line, but a geodesic. In such a space, motion of an un-accelerated entity would be along the curved geodesic and not along a straight line. The effect of this would be that the light from a distant star passing very near a massive object like the Sun would bend; it would thus appear to us as if the star had shifted position. Quantitative verification of this phenomenon provided one of the earliest supports for the Theory of General Relativity. If the object is a black hole, much heavier than the Sun yet smaller and more dense, the force of gravity would be strong enough to bend emerging radiation all around and stop it from coming out. Indeed, that is why black holes are called black.

There is another effect of gravity on light that we must not forget. Climbing out of a gravitational well, light photons lose energy - the wavelength shifts towards red (that is, it becomes longer).

211. Why is there no fire in the absence of oxygen?

Fire is the result of a chemical reaction in which energy is released. In our world, there are many combustible substances such as wood, coal, oil etc. A combustible substance is considered so because, upon reaction with oxygen, it produces other compounds along with a lot of energy. Fortunately, for most of these substances the reaction is extremely slow or does not start unless the temperature is raised above a specific threshold. Once the reaction is initiated, the temperature stays above the threshold and a raging fire can result. Even a child knows that a threshold temperature is required, because we always have to "light" a fire, be it a candle, the kitchen stove, a bundle of straw or a Diwali cracker. But your question is still pertinent - "Why only oxygen"?

There are many chemical reactions in which energy is released. All of them do not produce fire. They may produce heat and even light but fire, as we know it, is not a universal manifestation of such reactions. This is also true for nuclear reactions. A nuclear reactor produces a lot of energy. Tremendous heat is generated and high temperatures are achieved, but there are no flames. Flames of common fires are produced when gases react exothermally, there is convection due to heating and supply of gases is maintained from below. Their brightness is produced by the incompletely burnt, but incandescent, particles of materials such as carbon, wafted up by the rising hot gases. Carbon and oil containing materials are abundant on Earth. Oxygen is also available everywhere. A rise in temperature beyond a threshold therefore leads to a fire. Incidentally, we should realise that flames would not be seen in the way they are if there were no convection, for example in the micro-gravity environment of a satellite in orbit.

Nitrogen is the other abundant gas in the atmosphere. But the chemical structure of nitrogen is such that no exothermic reactions with these fuel elements are possible.

212. Water is colourless, water vapour is colourless, so why are clouds white or black and not colourless?

You must have noticed that clouds are not only white or black; at sunrise or sunset, they are also pink and red. This is because the colour of the cloud is dominated by the light that is scattered from the surface of a large number of tiny droplets. That colour is the same as that of the light falling on them. During the day when the Sun is up, it is the scattered light that filters through after many scatterings of water droplets. This makes the clouds white. When the sky is almost covered with thick clouds, little of the scattered light from the cloud comes down, while the part of the sky not covered with clouds is bright. This makes the clouds look dark. Dark is, after all, nothing but an absence of light. You might also think of the colour of the fine spray that is often seen near high waterfalls or tall fountains. That is also white or, when the fountain has changing multicoloured lights, the same colour as that of the lighting of the moment. I could also draw your attention to the whiteness of the foam on an agitated pool of soap water.

Dark clouds are usually thick clouds. Often they result from strong convection in which lot of moisture is carried up to high altitude.

213. Can stars exist in space without belonging to any particular galaxy? In other words, can they be isolated in space? Have such stars been discovered?

I like your question. It is true that we do not see any stars alone in the large empty spaces between galaxies. A single star is tinier and more insignificant compared to a whole galaxy than is a single person when compared to the whole population of the Earth. Such a star would be very lonely indeed as would be that single person. It is also hard to imagine how either of them could come into being in an empty void. Stars, like people, are also born. They have to be born out of something and it is difficult to imagine that that something would expend all its potential on a single star. If it is a star then, like people, it has to have its youth, maturity and old age. We do encounter such phases of life amongst normal stars. Therefore, we would not see such lonely stars unless there is continuous replenishment of such stars. One cannot think of the way this could be done; they could possibly be born within galaxies but for some reason be banished and flung out to deep space. It Is hard to imagine the processes that could result in such an event; there was a time when some astronomers advocated that the quasi-stellar sources with very large red shifts were actually stars that had been flung out of galaxies with high velocity! This hypothesis was never popular and is now forgotten.

It does seem that it is hard to be alone in our Universe, but it is possible that the Universe might contain far-flung entities, situated at great distances from the nearest galaxy; objects in the process of being consumed by a black hole, for example, that might appear to be isolated in space.

214. Since the speed and path of the light is unaltered by the motion of the source, why don't we see light bend, since our own Universe is in motion?

The Theory of Relativity does not abolish dynamics or conservation of energy momentum. The speed of light is the same in all frames of reference but other things change to ensure that laws of dynamics are not broken. One does different transformations in going from one frame of reference to another. The direction of light would look different in different frames of reference -also its colour, or the energy of its

photons. Light is also bent by gravitation. One of tests proposed for the General Theory of Relativity was to quantitatively compare the prediction in this regard with observation. The bending of light is now utilised for detecting a host of astronomical phenomenon through gravitational lensing. The point is that anything that can bend light in a predictable way can also be used for making a lens, which is but a device that can be employed for concentrating (or diverging) light from a source to produce an image.

Just to give a common example, consider the decay of a neutral pi meson (the pion). In the rest frame of the pion, the two photons into which it decays go in opposite direction, so that the net momentum remains the same i.e. zero. On the other hand, the angle between the two photons in the laboratory frame would depend on the energy of the pion and the angle at which the photons were emitted in the pion rest frame. Indeed, the measurement of this angle is used to estimate the energy of the neutral pions in the laboratory frame.

215. Research seeks to prove that matter is quantised. Can these quanta be continuous and have infinite density?

The search is not to "prove" that matter is quantised. The search is to seek models or theories that would describe the total Universe in "a unique way. Such a search postulates the existence not only of particles already known to be in existence, but also of particles to be later discovered. It is not clear how this search would end. The explorers are conscious that the theory may have to be corrected many times or even discarded and an entirely new approach followed. The particles that have so far been discovered are discrete in their mass and other properties. They are not continuous in the sense you mention. This field represents an intense effort that builds on the work of many creative men and women. The field is exciting, even though arduous, and the goals are audacious.

216. If white light is passed through a green prism, which colour will deviate the most?

This is an interesting question with a simple answer. If the prism is green, the material of the prism absorbs all colours other than green. Only the green light will emerge and it will deviate as green light should.

217. Yesterday, I saw a tiny object moving in the sky at a very high altitude. It appeared like a moving star. My friend thought it could he a meteor or a comet. It had no tail. It was just a slow moving white dot in the black sky. What could it have been?

I do not think you saw a meteorite. Meteorites would move very fast and would change their brilliance as they burn up in the atmosphere. I do not think you saw a comet because a comet, being very far, moves rather slowly across the sky, besides being a bit fuzzy and having a tail. It could be a highflying airplane. Such planes, when flying at an altitude of 10 kilometres or so, can take a few minutes to cross the sky. It could also have been a satellite. If it was only an hour or two after sunset, a satellite in a low Earth orbit would still be sunlit and would be seen easily. This would also be so an hour or two

before sunrise. I remember seeing, at about four a.m. one morning, the first Sputnik launched by the Russians in 1957. These low orbit satellites move across the sky in about 15 minutes. Geosynchronous satellites are not visible to the naked eye. You may have got lucky and glimpsed the International Space Station; indeed, it should be the brightest visible satellite when viewed at the right time. The reason is that it is the biggest artificial object in the sky and it is not at a very high altitude, being only a few hundred kilometres above the Earth. I have given you several possibilities and ruled out several others. The rest is up to you!

218. Why does the Universe appear black to us?

From out in space, the Universe does look black except for the stars and galaxies with which it is studded. This is so because no visible light is scattered in our direction from positions and directions that do not have a star.

This explanation does not account for the darkness of the night sky if we presume that the Universe is infinite and static. This is because in such a situation, all directions in the sky would point to a star and we will not need any scattering to brighten up the sky. Indeed, any point in the heavens will look as bright as the Sun and it would be impossible to explain the observation that it is dark at night! This is called Giber's paradox: "Why is it dark at night". This paradox is resolved by invoking the Doppler shift of radiation due to the expansion of the Universe. Doppler shift is easily understood and detected without an instrument when dealing with sound waves. Standing on a railway platform and listening to the continuously blowing whistle of a fast train going past the platform is enough. You would find that while the train is approaching you, its whistle is shrill but transitions to a lower note when it goes past you and starts receding. This happens because the number of waves hitting your ear every second increases when the train is speeding towards you and reduces when it is receding.

There is one kind of radiation in which the Universe is not at all dark. If we had eyes that could detect microwave radiation, we would find that the Universe is fairly, and equally, bright in all directions, I am referring to the Cosmic Microwave Background Radiation. But then this also is believed to be the Doppler-shifted radiation from an earlier hot, dense state of the Universe.

219. What is cloning? How is it different from mere artificial insemination and subsequent reproduction?

In the process of artificial insemination, a sperm (from the male) and an egg (from the female) are incubated together. Fertilisation occurs, resulting in an embryo, which is then implanted in the uterus of a female to develop further. The attributes of the resulting child would depend upon genes inherited from both parents. In cloning, one follows the following steps:

> A cell is isolated from the tissue of an animal, and its nucleus (which carries genetic information) is removed.

> An egg is isolated from the ovary of a female, and its nucleus is removed.

> The nucleus isolated in Step 1 is implanted into the nucleus-deficient egg created in Step 2.

> The resulting "embryo" is then implanted into the uterus of a female of the same species to develop further.

For example, in the case of the first successful cloning of an animal, scientists transferred the genetic material from the nucleus of an adult sheep's udder cell to an egg whose nucleus had been removed. Notice what we are doing.

The embryo is like a factory. Its nucleus gives Instructions as to what has to be produced, thereby determining the entire developmental programme of the organism. Cloning replaces the existing instructions in the female egg by those relating to a fully-grown individual. If the procedure is successful, the result is a clone of the person or animal whose DNA (residing in the nucleus) is implanted. I suppose in actual practice some compatibility between the "factory" and the nuclear "instruction sheet" would be required.

220. Why is blood divided into different blood groups in humans? Is this division applicable to lower animals as well?

Everybody's blood looks similar, but it is not exactly the same. Cell membranes of red blood corpuscles can carry two different types of molecules. These have been named A and B. Our immune system recognises this difference. As a result, if B type blood is given to a person with A type blood, a war begins which can have serious consequences, The same happens to a person with type B blood when given A type blood transfusion. There is a serious incompatibility. There are other individuals whose red blood corpuscles carry both the A and the B type molecules. These individuals are lucky because their immune systems cannot discern as "foreign" or incompatible either type of blood - it is seen as one's own and so no "fighting" ensues. People with neither A nor B molecules are said to have a blood group O; they can receive blood only from those who have O type blood. On the other hand, such people have usually been regarded as universal donors because their cells would not introduce any molecule that might trigger a war. However, this wisdom has begun to be questioned in recent years. Thus, blood grouping has to be respected because of immunological reasons. I am sure there must be some restrictions amongst animals also but I am not in a position to give details.

221. Why does intelligence between humans differ?

All living things, including plants, are made of roughly the same material. What makes them living is that they have a capability of self-replication -they can make babies and multiply. The information that controls their growth resides in their DNA. These instructions are detailed, but they are written in a language that is similar for all life. The instructions that make each of us what we are come from the genes we inherit. These genes contain contributions from both parents. Therefore, it is not surprising that there would be some differences between us. We may have basically the same architecture and similar ways of growing, but we do look different - we even behave differently. Even siblings differ because the embryos from which they grew might not be exactly the same. It is possible, therefore, that there would be differences in the brain sizes and

configuration between different individuals. The capabilities of the brain also grow. The pattern of growth may depend on physical and cultural factors. But in essence, there is little difference between the intelligence of two healthy individuals, even though a slight edge does matter. The point to appreciate is that even though we come from the same material, the combination of the same genes, we are not like coins stamped out by a machine; chance and statistics also come into play during inheritance.

222. Since all natural products are from plants, how do they differ in taste?

You know that all plants are not the same even though the basic molecules and atoms that go into making them might be the same or similar. We might even wonder why plants are plants and not animals. Using the same bricks and stone, you can build a Taj Mahal, a temple or the Pyramids of Egypt! Structure and design are crucial.

Let us now come to taste. The sense of taste is remarkably complex. It is sophisticated, with a great discriminating power. Our palate has a large number of receptors of different kinds. We sometimes call them taste buds. They can be thought of as sockets of complicated design into which only the molecules of a compatible design or shape can fit - this is like keys fitting into, and opening, specific locks. When a fit occurs, a signal goes out to the brain, eliciting the sensation of a specific taste. Several different types of receptors working in concert give us an amalgamation of sensations, resulting in a rich variety of tastes. Sometimes even the receptors in our nose that give us our sense of smell, work together with the taste buds to enhance and enrich the flavour of what we eat! Again, design and structure matter.

223. Why do we dream?

The phenomenon of dreams has been studied in detail by many experts. There are a large number of books on this subject. I do not think that an ultimate understanding has been reached, just as we still do not quite understand the mechanism of thought. But I will still attempt a short, qualitative answer.

It is clear that our body needs sleep; the brain and the central nervous system need rest. We also know that the entire office of the manager, our brain, does not shut down while we are asleep. There is an enormous amount of delegation of power and autonomy. We do not stop breathing when we are sleeping. The heart rate might slow down a bit, yet it’s beat keeps our blood flowing; our digestive system keeps working as well. Many of our senses are given a holiday and yet kept on alert should there be a need to take action.

There are a lot of images and stories residing in some structures of the brain. When we are awake, these are under conscious control. On the other hand, when we fall asleep, they are still present but they are unsupervised and have some freedom to combine in odd ways, often responding to strong experiences - some very recent and others very old, fished out from the bottom of the storage file. The editing and serialisation of images and thoughts might seem random but even the randomness seems to have some logic. Those impulses that are suppressed while we are awake become free to operate and be experienced. I have no doubt the world of dreams is important because we are not only that which we force ourselves to be while we are awake.

Given the fact that the "manager" needs rest while we sleep, and also given that the brain cannot completely shut down, it would be surprising if the bits and frames that represent thoughts and images would not resort to some play when the normally stringent control is somewhat relaxed. Some, more than others, have argued that study of such play is crucial for understanding consciousness.

224. If a person falls asleep and begins to snore, why doesn't he hear himself? And why can his snoring awaken a person sleeping next to him?

Some time ago I had received an equally interesting question. The questioner had asked "Why don't we yawn or sneeze when we are asleep?" Not being sure of how to answer this, I turned to my friend Dr. D. Balasubramanian. I know that your question is rather different, and I will come to it presently, but you might be interested in what my friend Balu had to say. I reproduce his reply below in its entirety—

"Sorry to have delayed my response so long. I was away, and then I had to consult physiologists!

While we are sleeping, half our sensory systems are put on hold - the process is referred to an inhibitory control of reflexes. For example, urination, bladder control etc. These come by a process of training - hence infants are trained for "su su" or "potty" and the like. When all works well, we suppress some of these while asleep. Hence, no yawn or sneeze while sleeping. But if you were to deliberately bother someone, the perturbation may override the control and you can cause him/her to react.

I hope this is OK. Best regards— Balu"

Let use now turn to your specific question. It would seem that even if we cannot rid ourselves of the annoying snoring habit, we do train ourselves to ignore the disturbance of our own snoring, because otherwise we would never be able to sleep. This is also an inhibitory control of our senses. We develop the capability of distinguishing between the self-disturbance of snoring and that which is not self-generated - the snoring of others.

225. Some recent studies have shown that laser beams can push things in a vacuum. Can such forces alter the movement of the Earth?

A laser beam does have energy and momentum, much like a bullet or a fast-moving cricket ball. It is not surprising that such beams can push things around. The interesting thing about the laser experiments is that the beams can be very precisely tuned and manipulated to accelerate or slow down individual atoms. Much beautiful science is emerging from these experiments. Anything we do on the planet itself can have little effect on the dynamics of the planet. We, and the tools we design, are not powerful enough. It is true, however that if our activities, over a long period, result in a significant shift of mass of the Earth towards either the poles or the equator of the Earth, we might slightly alter its period of rotation, and hence the length of the day!

226. When it rains, a very characteristic smell emanates from the soil. What causes this to happen?

The smell of the Earth after the first rain is very special. I too have wondered about its origin. When it rains after a long dry spell, many life forms like insects and worms begin to emerge from below. I am sure that the secreted and excreted products (including vapours and gases) of these subterranean creatures come to the surface. An important component of life in the soil is the Streptococci family of bacteria; these organisms are responsible for processing all manner of organic matter and converting inorganic Earth into soil. The volatiles produced in this process contribute significantly to that special fragrance of the Earth after the first rain. I have been informed that this smell is not exactly the same everywhere in the world. This is expected, because of the variety of life on the Earth is different at different locations and at different times of the year. I am much taken with the understanding that the Earth gives out a fragrance after an infrequent rain because it is alive, and is intimately engaged in the myriad functions which make our life possible. After all, how would we grow anything if there were no soil?

227. A stone dropped *from* my hand falls to the Earth's surface due to gravitational attraction. The same force attracts the Moon and the Earth as well. Why does it then stay in orbit and not collide with the Earth?

One way of looking at the orbital motion of the Moon around Earth is to say that it is continuously falling towards the Earth. It does not hit the Earth because, simultaneously, it also has a tangential velocity. Even to put an artificial satellite into the Earth's orbit, we raise it up to a certain height with rockets, but we also impart upon it an appropriate tangential velocity. For an orbiting satellite in a circular orbit, the force of attraction due to gravity must be balanced by the centrifugal force due to the circular motion of the satellite. So, if you do not just drop the stone but also give it the right horizontal speed, you would have launched a satellite, a new moon.

228. When I point my torchlight towards the sky, how far does the light travel? Does it ever stop?

There is no end point of light if it is not absorbed or scattered away by intervening matter. It would go on and on but eventually become too weak to be detected. This weakness comes from the fact that it would spread over a larger area as it travels. If your light were to travel cosmological distances, its character would change due to the Red Shift. The Red Shift is nothing but reduction in the energy of photons because the source is moving away from the observer. Reduced energy of photons implies increase in wavelength of light. This effect is also called the Doppler Shift. You can perhaps imagine that someone, very sophisticated and clever, looking Earth-ward from a distant galaxy, might be able to observe your torchlight in the infrared or even in the microwave frequencies! But it will be a tough task because the natural background at these frequencies would be very large.

229. It is believed that once we learn how to control the heat arising out of the fusion of hydrogen atoms, we will have access to limitless sources of energy. Hydrogen fusion occurs on the Sun and results in the production of ultraviolet radiation; we are fortunate that the ozone layer protects us from its effects. Even if

controlled fusion becomes a reality, will not the accompanying ultraviolet radiation be harmful to humans? If this is true, why are we pursuing this technological objective?

You are right to be concerned about the effects of radiation. Radiation can be ultraviolet, X-ray, gamma rays, or of any other kind. There are concerns about the safety of nuclear reactors that currently produce a significant fraction of the total energy used in many developed countries. The radioactivity and the fission products would be dangerous if released in the environment. Therefore, great care is taken to ensure that containment of nuclear reactors is efficient and foolproof. The radioactive fission products are stored for decay in specially built containers, some times after being converted into a glassy substance. In spite of all the precaution, worries persist in some quarters that some day a serious accident might occur.

No large-scale energy production method is without risks and, sometimes, undesirable costs. Thermal power plants which use large amounts of coal, oil or gas, pollute the atmosphere, besides releasing large amounts of carbon dioxide, a gas that contributes to global warming. One might add to this the inevitable accidents in production and transport of large quantities of fuel. You might remember hearing about marine disasters where oil tankers spilled vast amounts of their cargo in open sea, resulting in enormous damage to marine life and neighbouring beaches.

Let us now come to your specific concern about fusion reactors, should they become a reality in the coming years. It is useful to understand that the energy release, in both fission and fusion, comes from nuclear reactions in which the total mass of the reaction products is less than that of the initial reactants. The real world is so constructed that this is possible either by breaking up very heavy nuclei, as in fission, or by fusing together very light nuclei, as in fusion. Radioactivity is produced in fusion also, but it is not so long-lived or chemically hazardous. For fusion, the starting raw material (hydrogen) is much more abundant than the starting raw material for fission (uranium); it is for this reason that fusion seems an attractive prospect. There are technical hurdles to be overcome and, while the fuel is cheap, it is quite possible that the initial cost of setting up a fusion reactor might become exorbitant.

You might well wonder how the Sun carries out fusion so effortlessly. The Sun, like all stars, is very hot at the centre; the temperature is of the order of 15 million degrees. At these temperatures, the thermal energy of protons is high enough for them to get close to each other in spite of the fact that they are both positively charged and repel each other. This closeness is imperative for nuclear force to come into play. For building a working fusion reactor, we have to attain such high temperatures and contain the plasma for a sufficient length of time to get a net gain in energy. No container made of ordinary physical materials can survive such temperatures. Containment has to be devised by using magnetic fields in configurations for which the particle loss is negligible. For the Sun, this is no problem; the force of gravity is enough.

The energy produced in the interior of the Sun is not in the form of ultraviolet radiation. It is particulate radiation, X-rays and gamma rays. This energy gets converted to other forms while being transmitted through the mass of the Sun. The temperature at the surface is a mere 6000 degrees. Most of the energy at this temperature is in the visible part of the spectrum, but some does come out as ultraviolet light. “Ultraviolet” refers to

wavelengths shorter than that of violet colour. The high-energy end of the ultraviolet is absorbed in the atmosphere through interactions with air molecules. The lower end of the ultraviolet would get in if it were not absorbed by the ozone layer. But we should not knock all the ultraviolet radiation we receive from the Sun. If there were no high-energy ultraviolet, the oxygen molecules would not break up into atoms. If there were no free oxygen atoms, we would not have any ozone either. To remind you, ozone is a molecule with three oxygen atoms and is formed when an oxygen molecule combines with an oxygen atom. We are kept alive and healthy through a complex set of circumstances.

Incidentally, shielding living things from any ultraviolet or other radiation emanating from a fusion reactor, when it does come into being, would be a rather simple affair. There might be other arguments against this technology, but the particular concern you expressed should not dissuade us from building fusion reactors when they do become technologically feasible.

230. Is rebirth possible? Can people remember previous lives?

This is a matter of faith, not of science. I am "I" because of my genes and the environment in which I was brought up. This exact "I" cannot be reborn unless I am cloned; even then there would be differences, because the genes taken from me for the purpose of cloning might have undergone some mutations since the time I came to be.

I know there are some stories about children remembering their previous birth. One should perhaps ask the following question; were this true, how come all of us don't remember? But I do not want to get into an argument over this. Those who have been persuaded into believing in the phenomenon of rebirth will probably continue to do so. There is really no harm if they do. Perhaps this belief is a marvellous incentive to behave ethically in this life. It also helps in accepting one's adversities with equanimity.

231. I saw a picture of a growing embryo in the ovary of a female; it was made up of a whitish jelly-like substance. How can that liquid acquire the shape of a human? How can strong bones find a place in between the liquid?

Embryos do not exist within the ovary (which contains unfertilised eggs), but are implanted in the uterus after fertilisation. Nevertheless, your question is well taken. Growth of a living thing is a wonder and every developmental step is not fully understood. But what one does now understand is the role of the information encoded in our genes and contribution of the information from both parents in the development of the embryo. The basic ingredients for growth are nutritional, but the processing into forms and structures is on the basis of programmes in the genes. The operating system of living things is very much digital and less error-prone than our most sophisticated computers. The white jelly-like thing you describe is full of millions of factories, in the form of cells, working independently, sharing information, sequencing, controlling, and providing feed back information and what not. The bones, muscles, joints, arms, legs, fingers, nails, hair and all the complexities of heart, brain, lungs and liver arrive out of a preset design. All the information is stored in our genes, which are shared by all the cells. There is little room for a communication gap. Living things are not mass-produced as

complete, functioning entities, but constructed molecule by molecule according to detailed instructions.

232. Why are most automobiles front-engined? If there exists a scientific reason for this preference, how do cars like the Volkswagen "Beetle" exist?

I can only guess. One reason must be the dominant convention - in spite of the "Beetle". It makes sense to place the radiator of a fast-moving vehicle right in front where the speed of the car itself helps to cool the radiator and hence the engine. Possibly, the engine of the "Beetle" has been engineered such that it can be adequately cooled by a strong air-cooling system.

233. Why do some planets have atmospheres while others do not?

Let us look at the fundamentals impinging on a possible answer to this question. It is quite clear that three factors can enter into the exploration of this problem. These seem to be the mass of the planet, the temperature on its surface, and availability of a material that would be gaseous at that temperature. If the mass is too low, say like that of the Moon, gravitational attraction on a molecule of air introduced on its surface would not be enough to counter the thermal velocity of the molecule when it comes in contact with hot soil of the Moon during the day. At some time, this molecule would start travelling in a direction away from the Moon, would keep going and be lost to space. If the Moon were much colder, say at a temperature below the liquefaction temperature of air, there might be a faint atmosphere representing the vapour pressure of solids and liquids at that temperature. In general, small planets will not retain gases in the atmosphere and those that are hot, even less. Our Earth has a difficult time containing hydrogen and helium because at the temperature on the surface, the thermal velocity distribution of the molecules of light gases extends up to values greater than the escape velocity. They would be first transported to the upper atmosphere through convection and finally escape. On the other hand, Jupiter can easily restrain these gases within its atmosphere due to its much stronger gravity.

234. What are cosmic rays and for what are they used?

It is difficult to describe the fascinating field of cosmic rays in answer to a question like this. In short, one could just say the following:

Cosmic rays are nuclei of elements ranging over the whole of the periodic table (and up to twenty orders of magnitude in energy) that pervade our galaxy and the space beyond. They bring to us samples of matter from far distances, carrying information about their sources and the processes of their acceleration. They also carry the wounds of their encounters with thin matter in the interstellar space. In this sense, cosmic rays represent a distinct and specific astronomical and astrophysical signal, specially connected with extremely high-energy phenomena. Study of their energy spectrum and composition has provided invaluable information about our Universe. Until the mid-fifties of the twentieth century, cosmic rays provided the only source of particles whose energies were high enough to produce mesons of various types in their interaction with

other nuclei. Indeed, cosmic ray physicists discovered a large fraction of the new particles that came to light during the twentieth century. These include the positive electron, the neutron, the muon and the pi meson and a host of heavy unstable particles that came to be known as strange particles. The role of cosmic rays in particle physics decreased after the arrival of several high-energy accelerators. But even now, the highest energies are available only in cosmic rays and, for answering some fundamental questions, there is a renewed interest.

I could talk about many aspects of this fascinating field that led to the birth of a class of scientists who easily ranged over the fields of astronomy, cosmology and particle physics. Their number has increased in recent years. Perhaps it would be worth pointing out that cosmic ray studies also produced the carbon-dating method so much in use in the field of archaeology.

I can say from personal experience that, besides all the exciting science that has emerged from the field of cosmic rays, there was also enormous romance in working in this particular area. People experienced the challenge and the thrill of flying balloons, working in deep mines (down to 2 kilometres below ground), and conducting experiments in the depths of the ocean, high atop mountains and aboard rockets and satellites.

235. How do honeybees identify their own honeycombs?

Honeybees are very sophisticated at position location and navigation. It is known that they use the Sun as a guide. They also appear to have a good memory. They convey the information of a new find of food to the hive through an amazingly clever dance language. The dance indicates the direction and distance of the food source with respect to the direction of the Sun in the sky! If it is dark inside the hive and a light bulb is switched on, the dance is modified to include the light bulb as a new reference direction! Since bees have pictorial memory of some sort, a direction-finding mechanism and a way of reckoning distance, they are probably better equipped for getting back home than any of us!

236. What is the principal behind the rotation of a top?

A top starts rotating because you impart a spin upon it, perhaps by pulling on a string wrapped around it. I am sure that this is not what your question relates to, however. You are probably wondering why the top keeps rotating for as long as it does. Linear momentum is conserved unless some force comes into play. So also is angular momentum. The top stops rotating after a while because of the force of friction, of the air as also the ground on which the tip of the top rests. Incidentally, this is also the reason the Earth keeps rotating; unlike the top, the Earth goes on and on because the retarding forces are negligible.

237. Black holes consume every thing due to their massive gravity, yet there was a report on the Discovery Channel about a “galactic” search-light phenomenon,

where a pulsating light was recorded emanating out of a black hole. Is this possible? If it is, doesn't it mean that this "galactic" light can travel faster than normal light?

The phenomenon you refer to can be explained without postulating the emergence of light out of a black hole. I am sure this black hole (as all others) was detected because an object that did emit light seemed to be revolving around something massive, the latter object being not visible itself. Binary stellar systems are quite common. One of the stars, the heavier one, can evolve to become a black hole while the other keeps going around it. Depending on the distance between the two objects, there could be matter flow, sucked out from the star to the black hole; the matter, while spiralling down towards the black hole, would heat up and emit radiation - this radiation can escape because it has still not entered the prison of the black hole. *The* radiation could have directionality and a sweeping character resulting from the orbital motion of the star. It is also conceivable that the star that has not become a black hole has reached the stage of a neutron star and has become a pulsar. The pulses given out by the pulsar do not comprise of the light escaping from the black hole itself. The analysis of the orbit of the pulsar could be used to assert that there is a black hole in the middle.

238. How many dimensions does a sphere have?

A sphere, like anything that has length, breadth and height, is a three- dimensional object. Therefore, it has three dimensions. In other words, just three coordinates are required to completely describe a sphere. I suspect that you are really thinking about the surface of the sphere. If you already know that it is a sphere of a given radius, only two coordinates are enough to define a point on the surface - for example, just the latitude and the longitude can give the location of a city on the globe.

239. Why is the Earth flat at the Poles?

Earth is not flat at the Poles, but its radius in that direction is smaller than that near the equator. In other words, the Earth is not an exact sphere but an "oblate spheroid", the polar diameter being less than the equatorial diameter by about 43 kilometres. The difference is about one part in 300.

The reason for this departure from the shape of a perfect sphere lies in the fact that the Earth is rotating around its axis and the equatorial region experiences a centrifugal force away from the centre.

Such effects play a significant role in astrophysics - for example, in the formation of stars and planetary systems and the morphology of the Universe. Spinning and gravitating matter tends to form thin discs, much like the shape of our galaxy, the Milky Way. This effect must have also been involved in the formation of our Sun and its family of planets, all moving in the same plane.

240. What is the longest time spent by humans in space without contact with the Earth? On which space station was this record established?

I have forgotten the exact figure, but it is many, many months. The space station was definitely the Mir, belonging to the old Soviet Union. The astronauts (or cosmonauts as

they call them in Russia) were not without contact with the Earth. Besides radio and television, they also had supply rockets arriving periodically, and colleagues visiting for shorter duration. This should not give an impression that living in micro-gravity conditions in a relatively cramped environment is much fun. The body is confused, metabolism has to re-adjust, bones tend to get weaker and the packing between the vertebrae of the spinal chord expands a little, resulting in an increase in height by a few centimetres.

241. Why does hair stand on end on a chilly morning?

I do not really know the answer, but let me hazard a guess. When it is cold, the body would like to reduce the loss of heat, particularly due to evaporation. Perhaps closing of the pores on the skin tends to make the hair stand up like little poles. While I have risked this answer, I am not even sure of the observation. Please take this explanation with a pinch of salt and try finding a more reliable answer from elsewhere.

242. Please tell me about 'Uttarayan' and 'Dakshinayan'.

I do not know what you really want to know. You are probably referring to the periods when the noon Sun is as high as it can get in the northern and southern hemispheres. This is clearly connected with the fact that the Earth axis is tilted at 23.5 degrees with respect to the plane in which it goes around the Sun. This is what gives us our seasons. The mid-day Sun is vertically above the Tropic of Cancer close to the 21st of June and on the Tropic of Capricorn around the 22nd of December. I suppose Uttarayan is the period of the year, from end December to end June, when the Sun seems to move towards the north. Similarly, Dakshinayan would designate the time of year from end June to end December when the Sun seems to be moving southward.

243. If I am in Space, travelling in a moving spacecraft and I release a ball outside the spacecraft through the window, what will be the motion of the ball? Will the ball move with the same velocity as the spacecraft? Will the ball remain suspended in Space at the point where I released it?

There are two possible scenarios. If you are in a spacecraft that is being accelerated by its rockets and is not in a condition of free fall, the ball will become a free falling object. A microbe sitting on that ball will become weightless. The only residual force on it will be due to the ball itself. The ball will quickly separate from the spacecraft. Sitting in the accelerating spacecraft, you will not be in a condition of weightlessness till the time the rocket engines are shut off.

I suspect what you are really interested in is the second scenario, where your spacecraft is already in orbit and you are in a state of free fall or weightlessness. Under that condition, the ball will keep moving along with the spacecraft, unless you happen to give it some relative velocity during release. Let us assume that no momentum has been imparted during release. Let us also assume that your experiment is carried out in deep Space where the decelerating force of air friction can be neglected. In that situation, the ball will stay rather close to the spacecraft because of the mutual gravitation between the

ball and the spacecraft. Indeed, the spacecraft will become a sort of shepherd, herding together small debris that might be gently released from its surface or that drifts into its neighbourhood. Such shepherding is believed to be a mechanism influencing the formation and shape of Saturn's rings, for example.

244. My locality in Kollam, Kerala, had recently experienced weak seismic activity. The water level in the wells has risen dramatically and cracks have appeared in a few houses. No one really knows whether the tremors will get worse; people are on edge, since these happenings are unprecedented. Is there any cause for alarm?

I am sorry, but I am not in a position to provide any definitive answers without knowing the precise facts. There have been reports of ground water levels changing after earthquakes. This is not surprising. Connections to aquifers can become more or less efficient after the rocks and impervious layers in the Earth break up during an earthquake. That in itself should not be a cause for undue alarm. But it is definitely something that needs deep and detailed study. I have heard more stories of a rise, rather than a fall, in water levels as a result of seismic activity. I wonder if this could be due to the fact that we have been over-exploiting ground water in some areas while the underground reservoirs in other areas (perhaps not so suitable for agriculture or habitation) remained relatively isolated and untouched; earthquakes might open channels to these reservoirs. If so, it is good, at least for a while. Incidentally, I remember a time when some people used to advocate the use of underground atomic explosions to increase the porosity of the subsoil. I am glad this was not tried on any large scale, since it is clear that earthquakes cannot always be beneficial in this regard.

It has been a rather discursive answer. It is only some loud thinking without much knowledge or analysis to back it. Treat it as a chat.

245. Why does the rain fall in drops?

Rain is the result of condensation of vapour when the air is cooled below the dew point. All the vapour in a cloud cannot condense at the same time and turn into a large pool of water. Pockets of air move up independently and slowly cool till condensation begins and water droplets form. It is believed that most raindrops start out as tiny ice crystals - so tiny that they float down, slowly accreting more moisture on the way; at lower altitudes, the crystals melt into water droplets. In colder climates, the crystals reach the ground as snowflakes.

246. How do bacteria spoil curd?

Curd is made by the action of bacteria on milk. Milk is a nutrient; it is a medium in which bacteria can multiply. The generation of curd is a biotechnological process for which milk is inoculated with known bacteria, usually provided by mixing the milk with a little bit of previously made curd. Growth rate varies with temperature; in cold weather, the curd takes a long time to set. In warmer conditions, bacteria may over-multiply and the curd can turn a bit sour.

You might also wonder why milk, when not adequately refrigerated and left in the open for a long time, spoils instead of turning into good curd. There are bacteria of various types in the environment, all of them hungry for food. Their action and metabolism is different from those of bacteria we use to make curd and may lead to the production of harmful products.

247. There are many satellites orbiting the Earth. Why don't they collide with each other? What happens to them once they are too old to function properly?

Yes, there are hundreds of satellites up there. But Space is very big. Consider a very special case where the crowding is the maximum. This is the geostationary orbit, 42,000 kilometres above the centre of the Earth, over the equator. Let us assume that we station 360 satellites in that arc, each separated by an angular distance of 1 degree from its nearest neighbour. The physical distance between them would be 2 times pi times 42,000, divided by 360, namely over 730 kilometres. A satellite is roughly the same size as a motorcar. Thus, the physical crowding would be similar to having a total of three cars moving at well-defined speeds between Delhi and Chennai! A physical collision is possible only through intention and not through accident.

Nevertheless, crowding in the geo-stationary orbit is becoming a cause for serious concern for other reasons; this does not come from physical proximity in itself but the fact that the electromagnetic beams to the satellites and the emanations from the satellites themselves can result in interference of signals.

A satellite has a finite life-time. It can develop a fault in any of its subsystems due to electrical or mechanical malfunction. There is degradation of its power generation capability due to radiation effects on its solar arrays. And finally, it reaches the end of life when the fuel on board, which is used for control and orientation, is exhausted. Low Earth orbit satellites have a shorter life because the degradation of the orbit due to the air drag becomes significant and has to be continuously corrected. So what does one do with satellites that have become obsolete, outlived their usefulness or totally failed? Those in low Earth orbit are manoeuvred to de-orbit gracefully; the smaller satellites burn up almost completely during descent, without causing damage on the ground. Higher orbit satellites, including those in the geo-stationary orbit, stay in orbit as non-decaying dead bodies, unless they are pushed up to a 'graveyard' at a slightly higher altitude. All of them need to be shut down electrically to eliminate their radio interference. While these guidelines are universally accepted, there is continuing concern about the accumulating junk in orbit. It is speculated that after long enough a time, this junk would break up due to collisions with meteorites or other floating junk and we might end up with Space rings of artificially injected terrestrial muck which will alter the Space environment permanently. It is sad but true that we humans do not show too much concern or regard for the coming generations.

248. What does Albert Einstein mean when he says that Time and Space are related?

If no signals can move with a velocity greater than the speed of light, it is not possible to define simultaneity of events without considering both Space and Time. There is no

instantaneous action at a distance. When we look at the Sun now, we are actually looking at how it was 8 minutes ago, 8 minutes being the time light takes to travel from the Sun to the Earth. “Now” on Earth, the Moon, the Sun or a star cannot be the same.

249. When something appears impossible at a particular point of time, it is referred to as fiction; if and when it becomes reality (for example, airplanes or cellular phones), we label it as science. Is this fair?

Fiction is a marvellous thing. If someone says that the *Mahabharata* is perhaps the greatest piece of science fiction ever written, I consider it to be a great tribute to the richness and imagination of that amazing epic. If humans could not create fiction, they would never have been very creative. Coming to the specifics of your question, I hope you do not want to refer to cellular phones and airplanes as fiction! They are not because they exist and, more importantly, we understand why and how they work. For fiction, understanding and feasibility are not as rigorously demanded. That is why all fiction does not become reality.

250. What burns at the tip of the wick of a candle?

1. Gaseous wax 2. Solid wax 3. Liquid wax 4. Wick

Thank you for your multiple-choice question. I see that the quiz culture has really taken hold!

The heat of the beginning flame melts the wax, which then rises into the wick. The hydrocarbons produced through heating begin rising as a gas due to convection, carrying the air rushing in from all around. The bright part of the candle must be the incandescent carbon particles, while the hottest part of the flame should be at the top where efficient burning of the vapour takes place. If the wick or the liquid wax were burning, the candle would not blow out in a mild gust of wind. Blowing on chunks of red-hot coal does not extinguish them - it makes them burn brighter and more fiercely.

251. Stars are said to be formed by fission/fusion. Where does the energy to initiate such reactions come from?

Stars are not formed by fusion. Stars start shining because of fusion of the abundant hydrogen at their cores. Formation of a proto-star occurs through gradual accumulation of matter into a gas and dust cloud. The heating of the star is caused by the gravitational energy of collapse. When the temperature in the core becomes sufficiently high, fusion reactions are initiated. Incidentally, stars are controlled furnaces. The pressure of radiation flowing outwards stops further contraction of the star. An increase in temperature expands the star a little, thus cooling the core and reducing the rate of reaction. A decrease in temperature, on the other hand, makes the star contract a little, in turn increasing the temperature and, therefore the rate of reaction.

252. How can a mixture of salt and sugar be separated?

I am sure some messy chemical method could be used. It occurs to me that other methods that make use of the fact that the salt and sugar molecules have different sizes might be preferable. Membranes in living things are very cunning in this regard. They seldom do things by conventional chemistry for controlling the flow of biochemical substances across cell walls. Even the blood of the baby in the mother's womb is kept separate from that of the mother while supplying all the nutrition the baby needs. I am not very sure about the industrial process that would be brought into use should there be an urgent need to separate the salt and sugar in a solution.

This is perhaps not a satisfying answer, but I am too stupid and ignorant to think of something else without consulting others, I leave that consultation to other members of our community.

253. When naphthalene balls are dropped into a jar of soda, some stay at the bottom while others come up to the surface. Why?

I suspect this might be due to the fact that gas bubbles stick to the surface of some of the balls, making them lighter. This sticking event is probably a random statistical phenomenon, thereby affecting only some balls. I am curious to know how you happened to think of doing this experiment. What else did you try? What happens in plain water?

254. Why do astronauts not experience gravity, although they are orbiting around the Earth in a spaceship?

A spaceship orbiting around the Earth is itself almost "weightless". It is falling freely towards the centre of the Earth, but keeps missing it because of its tangential velocity. Another way of looking at this is to say that the force of the Earth's gravity upon the spaceship is exactly balanced by the centrifugal force arising due to its rotation around the Earth. It is not just the spaceship; but also all things contained within it are also similarly "weightless". This also applies to astronauts in the spaceship - they are also satellites of the Earth.

255. Electrons revolve around the nucleus, which contains positively charged protons and uncharged neutrons. Since like charges repel each other, why doesn't the nucleus break apart?

You are quite right in worrying about the repulsion between the protons in a nucleus. The stability of nuclei is understood by properly taking this into account. Nuclei are stable because, at short distances, another force comes into play. This is the so-called nuclear force. This is a short-range attractive force between all residents of the nucleus, and serves to counteract charge repulsion of the protons. Balance between all the opposing forces makes nuclei stable. If you look at a table of nuclear masses, you will find that while for light elements [such as carbon and oxygen), the number of protons and neutrons is nearly equal, in the heavier nuclei, the number of protons is much less than the number of neutrons. For example, the most abundant isotope of uranium has 92 protons and 146 neutrons in its nucleus. This is precisely because of the concern you have

expressed. Increasing the number of protons would make the nuclei unstable and, therefore, non-existent.

256. Is there a method of counting all the stars of the Universe?

We can't even see all the stars. Some are hidden by dust clouds, many more are in galaxies so far away that they cannot be resolved as separate entities even by the most powerful of telescopes. So how do we say that there might be a hundred billion stars in our galaxy and a hundred billion galaxies? Not by counting, but by estimating on the basis of sample counts in some small representative parts of the Universe. For example, for some parts of our own galaxy, we might count the stars in a tiny bit of an angle of view. Then it becomes a problem of repeating this exercise on selecting representative bits of the sky in all directions and doing the same. What remains then is to estimate the total volume in various representative bits. Remember the word "estimate" used above. We must I also remember even the largest telescopes looking at a narrow solid angle, may not see the objects that are too far away or much too faint.

To get an idea of the power and limitation of this kind of extrapolation, you could do an experiment; try to estimate the number of hair on the head of a friend. Just choose a square millimetre of the surface at a few representative locations, count the number in each and multiply with the; total surface area!

257. It is believed that fossil fuels like petrol are formed upon transformation of organic substances, a process that has been on-going for millions of years, and a process that is no doubt ongoing even in the present. Why are these fuels then referred to as non-renewable sources of energy?

I like your question. Partly because it clearly shows that we do not easily comprehend the length of time life has been around on this planet. This is also the reason most people do not understand how evolution could lead to the complexity and variety of life forms we see around us. Let us do an approximate, qualitative, back-of-the-envelope calculation. Let us assume, as you suggest, that resources like oil (and let us confine ourselves to oil for this argument) were created through transformation of the decaying organic matter in soil and sedimentary rocks. There is evidence that life has been around for a little more than four billion years. The proven, recoverable reserves of oil are estimated to be somewhat less than one hundred billion tons. This comes to an average accumulation rate of twenty-five tons per year. We are perhaps consuming something like one thousand million tons per year, which is forty million times greater than a possible renewal rate. And our rate of consumption is bound to rise as more and more countries industrialise. In a single century, we have made a significant dent in the wealth the planet took over forty million centuries to accumulate! The era of oil-based economies, including modern transportation systems, will be seen as an insignificantly narrow spike on a chart of human history drawn a thousand years from now.

In the end, let me say something about the manner in which I have done this calculation. It is not exact, but then we do not need exact numbers to make this argument. I might concede that I have not even looked up the figure for total consumption for oil in the world. I know that we consume over sixty million tons in India. We comprise one-

seventh of the world's population. We also know that twenty per cent of the world population consumes eighty per cent of its resources. With this information, it is easy to come to an estimate of 1000 million tons for the whole world. This figure may be wrong by twenty per cent but that does not vitiate our argument. I just wanted to stress that scientists routinely make such "guesstimates" for ruling out or considering hypotheses. In Hindi, you would call it 'andaz lagana'.

258. Does water exist on the Moon?

I do not think there is any evidence for existence of free water on the Moon. Water of crystallisation perhaps does exist. You realise, of course, that any water poured on the Moon will immediately vapourise and escape from the Moon. Even ice will sublimate. This is because there is no atmosphere on the Moon.

259. Will construction of a very tall building increase the time period of Earth's rotation round its axis?

In principle, yes. But the building has to be large, perhaps of continental dimension, and really tall to make a measurable difference. Moving the Earth mass to a larger distance from the centre of the Earth will increase its moment of inertia and conservation of angular momentum would require that the angular velocity decrease, or period of rotation increase, somewhat; the day would become a little longer than 24 hours.

Incidentally, there is some evidence that the Earth's rotation has been slowing down over millions of years because of the friction of tides. Difference in gravitational attraction of the Moon on opposite sides of the Earth causes two bulges of water in the oceans that move with the motion of the Moon over the Earth.

Another effect of this is that due to conservation of angular momentum of the Earth-Moon system, the Moon is moving away from the Earth at a rate of a few centimetres a year. This recession rate has been measured by accurate determination of the Earth-Moon distance by laser ranging experiments.

260. A mass is attached to a spring balance. If the mass is immersed hi a bucket full of water, what will happen to the reading on the spring balance? Will it decrease or increase or remain the same? I predict that due to the buoyant force acting on the mass, the reading will decrease. Am I right? Also, would the viscosity of the fluid have an effect? What will happen if we used castor oil instead of water?

You have yourself provided the answer. There will be a loss of weight and the spring balance will record this loss. This is true irrespective of the liquid you use; if the liquid is denser than the object you are immersing, the object will float - it will not exert any pull on the spring balance. Viscosity of the liquid does not matter, density does.

261. When there's a nip in the air, how does a woollen sweater protect us from the cool morning breeze and keep us warm?

We generate heat by metabolising the food we eat. Body temperature is maintained to within a fraction of a degree to ensure that the biochemical processes in our body proceed at an appropriate rate. The heat loss from the body occurs through radiation and through contact with the outside air. In addition, we lose heat through evaporation of the perspiration that bathes our bodies when we are excessively warm. Within limits, the internal mechanisms of the body work very well, varying the rate of metabolism and adjusting the skin temperature to suit the environment. To tackle the extremes of cold, the need for insulation is felt by many animals. Some animals grow a thicker coat of hair during winter. We humans learnt to wear clothes, initially made of animal skins and then of cotton, wool and synthetic material. A sweater is nothing but insulation to reduce the heat loss from the body. Wool is good for making sweaters because it contains a large number of air cavities; air is a bad conductor of heat. The structure of the sweater does not allow much heat loss through convection either.

262. Why do clouds look reddish-orange in the evening?

In the late evening, when it begins to get dark on the Earth's surface, the clouds can still catch the Sun's rays for a while longer, since they are high up. But, to reach the clouds, the rays of the Sun have to pass through the atmosphere almost tangentially. This distance travelled through air Is therefore very large. You can satisfy yourself about this by drawing a sketch of the round Earth with a thin layer of atmosphere around it; you will notice that at dawn and dusk, the Sun's rays have to traverse a much longer distance through the atmosphere than they would at noon. This long path through air leads to excessive molecular scattering. Orange and red light scatters away much less than the blue and green colours. Therefore, the clouds are illuminated by light that appears mainly orange-red. This accounts for your observation.

263. What is the nature of fire? Is it a solid, liquid or a gas?

Fire is neither of these. It is more like plasma in which positive and negative charges are temporarily separated and joined together to emit light and heat. It is not a thing but a process in which (believe it or not) some mass is being transformed into energy and some substances converted into others.

264. Is it true that unexplained happenings occur in the Bermuda Triangle?

The stories and fiction of the Bermuda Triangle have been carefully analysed. There is no evidence that the rate of marine accidents in that area is higher than would be expected for any hurricane-prone area. It has been shown through a serial analysis of the news stories and books written about this subject that the whole thing is a media invention. People like mysteries and elaboration of this mystery has sold a lot of books and magazines, and has spawned many films.

265. What are the salient features of an award-winning science project? What are the things the judges look for?

Choose a science project because you want to understand, design or build something — not because you want to win a prize. You will be surprised at how much you learn, and new knowledge is the best prize you can get.

266. Whatever I learn, I forget very soon unless I "revise" it over and over. Is there any way I could learn things the first time without the tedium of repeated study?

Learning is not meant primarily to answer examination questions. It is for understanding. If you learn without understanding, you are likely to forget more easily because you have not been able make links with what you have yourself observed or understood earlier. If you learn for understanding, the essence of the knowledge you gain will become part of you. This method of learning will be much more useful and fulfilling than simply becoming the human equivalent of a tape recorder, or a compact disc. Speaking more generally, it is profitable and enjoyable to study and learn with concentration, by immersing yourself in whatever you are engaged in.

267. Why are automobile tail-lights red?

The extent to which light scatters in the air depends on its wavelength. Red light scatters nearly 16 times less than indigo blue. Therefore, red light can be seen at a greater distance than light of any other colour. That may be the reason for preferring red whenever some thing is to be noticed from far away - red colour signals are used as stoplights at road crossings as also stop signals for trains. Think a little and you will also understand that the same physics also explains why the setting Sun looks orange red and why the sky is blue.

268. Why does a thin leaf-like membrane form on milk when it is left exposed to the air, but not when the vessel is covered?

Let me confess that I do not quite know the answer; this would be true of many of the questions that you send me. But let me present one explanation that any of you is welcome to shoot down.

I suspect you are talking of warm milk. When milk is heated, the cream globules along with casein, being lighter, come to the top. In an open pot, there is more cooling from the top because of evaporation and increased radiation. When hot. the cream is almost a liquid. If the water begins to evaporate, the globules of cream and casein coalesce. As they cool, the cream begins to get thicker and begins to look like a membrane.

When the pot is covered, evaporation from the surface is dramatically reduced. The cream and casein globules remain separated by watery milk that inhibits the formation of the membrane. But I suspect even in this case, you will get a layer of "malai", the membrane you talk about. So, there. Now every one can have a go at it.

269. Why do winds blow at high velocity before it starts to rain?

You must have seen curves demarcating high and low pressure zones in newspapers and weather report broadcasts on TV. When a low pressure is created, air from the neighbouring high-pressure zones rushes in from all directions. This rushing air is the wind we feel. If the air blows in from all directions, the only place it can go is up. As the air rises, it cools due to adiabatic expansion. The moisture in the air condenses and you get rain. Rain, therefore, arises due to the wind; the wind does not arise because it has started raining.

When this phenomenon occurs over the ocean over a large low-pressure area, it could result in a cyclone. The warmth of the ocean supplies the energy of the cyclone.

270. If sheep can be cloned, can humans be cloned as well?

I think it would become possible to do, some time in the not too distant future. Whether such a thing should be permitted, or is even desirable, is another question. Besides the obvious ethical questions, one should also remember that, at least at the level of technology that currently exists, the procedures entail high risk. There is something deeply demeaning about multiplying human beings solely on the basis of physical attributes. What's next? The elimination of "defective" humans? And besides, who we are is, to a large extent, determined by nurture and not simply genetic content. On the other hand, there might be much less concern about cloning individual organs such as the kidney, liver and even the heart as "spare parts". One can foresee a time when the old would keep a bank of spare organs for any eventuality. This could become quite an industry for the super-rich. I doubt if the rest of us will be able to afford the luxury.

271. If a person were flying faster than the speed of light, would he be able to see his past and future?

This can be only a thought experiment. Nothing can fly faster than the speed of light. But let us disregard this fact for a moment; we begin to accelerate and catch up with the leading edge of a light beam sent out by the flashlight in our hand and sit on it. Then, we look around and see nothing!! We would have arrived in a very unreal world in which there are oscillating electric and magnetic fields, which do not propagate! That is not light. In our world, oscillating electric and magnetic fields propagate.

But let us overlook the physics and the world we understand and assume that somehow a genie has transported us ahead of the light beam and we are awaiting its arrival. Then we will, of course, see things happening backwards, just as you would If you ran the film of a movie backwards. Hypothetically, we could then see into our "past". Fantasy is fine; I enjoyed the story *Time* Machine written by H. G. Wells. But, fortunately, the immutable laws of physics determine that scenarios like that will never come to pass.

272. Why are the keys of a computer keyboard arranged the way they are?

I believe it has something to do with the frequency with which various letters occur in the English language. The letters that occur more frequently are placed in a way that the

fingers of two hands can more easily access them -provided, of course, you are doing touch typing.

273. a. We sometimes play Holi with dry coloured powder. When you wet the powder, the colour appears deeper. Why is this so?

b. Why do wet clothes appear darker?

a. We see an object because the light scattered by the object falls on our eyes. This light also carries a signature of the object. The Holi powder looks red because all colours except the red are absorbed by the powder. But something else also happens. Some portion of the light falling on the powder is scattered at the surface because the velocity of light in the powder is slightly lower than in air. One usually says that the refractive index of the powder is higher than that of air. The scattered light does not interact with the pigment in the powder. It has the same colour as the incident light. Looking at the reflection of the Sun by glass or of a bright light by a coloured sheet can show that this is so. So, what happens when we wet the powder? Some of the light that initially scattered away from the surface now enters through the water interface and has a chance to come in contact with the pigment, leading to enhanced absorption. Dilution of the colour by scattered white light is also reduced. The result is a colour that's visibly darker.

b. We see things because some of the ambient light that is scattered from them reaches our eyes. When light falls on a piece of cloth, for example, part of the light is scattered from the surface and a part of it penetrates to some distance, wherein it interacts with the pigments that give the cloth its colour. The perception of a particular colour arises from the fact that all wavelengths that do not represent that particular colour are absorbed. The colour we perceive is diluted, because a certain percentage of the incident light scatters at the surface itself, without entering the cloth. If the incident light is white, the surface scattered component is white as well. Wetting the cloth reduces scattering at the surface; water is, after all, transparent stuff. A greater percentage of incidents light now enter the cloth. Therefore, the dilution effect of the ambient light is greatly reduced and the colour of the cloth appears to become deeper, or darker.

END